The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry, USDA, Forest Service, to develop and deliver technologies to protect and improve the health of American forests. This book was published by FHTET as part of the technology transfer series.

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Cover  Silhouette of a white bark pine on top of the National 2012 Composite Insect and Disease Risk Map.  
Cover design by Sheryl A. Romero.

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National Insect and Disease Forest Risk Assessment

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The Forest Insect and Disease Risk Map Atlas is a stand-alone compendium that includes several maps presented in this report and two maps for each risk agent or agent group examined in this assessment, summarized by watershed. The risk agent maps are arranged in alphabetical order by common name. This atlas serves as a tool and reference guide for resource managers to quickly identify priority and threatened watersheds and their causal agents. Watersheds provide a broad overview from which patterns across a large landscape can be identified easily.

The first three sets of maps show composite risk of mortality across all agents. These maps are shown in the main body of the report and are reprinted here for convenient comparison with the individual causal agent maps that complete this atlas. Following the standard pixel-based composite risk map is a watershed summary based on the percentage of total area at risk. The third map ranks watersheds by the cumulative basal area (BA) loss from all agents. Following the composite maps are two tables that summarize the models behind the Risk Maps. Table A (pages 72–73) summarizes the criteria (i.e., drivers for risk) used to model each risk agent or agent group and describes the importance of these criteria. It also lists the maximum realizable mortality rates’ used in the risk models. The maximum realizable mortality rate is a mortality ceiling assigned to each risk agent model that defines the level (rate) of host BA mortality for the modeled agent and can be attributed to a particular agent. When all of the risk criteria are at their maximum—i.e., have a risk score of 10 for every criterion (on a 0–10 risk scale, see Krist et al. 2007)—the BA mortality rates for risk scores lower than 10 are linearly scaled between 0% and the maximum realizable mortality rate. For example, if the maximum realizable mortality rate is 80%, then pixels having the highest possible risk score of 10 would experience 80% host mortality; pixels having a risk score of 5 would experience a 40% mortality rate, etc. Table B (page 76) provides a crosswalk between the pests and pathogens and their individual tree species hosts, as modeled in the 2012 NIDRM.

We provide two watershed-based maps for each causal agent.

1. Classification of watersheds based on the percentage of projected BA loss. Each summarizes the relative impact of that pest or pathogen and allows comparison between watersheds ranging from sparsely to heavily forested.

2. Ranking of watersheds by the absolute amount of BA loss. These identify the watersheds where BA loss potential is greatest.

The classification maps are based on the percentage of BA loss, so they are helpful for understanding the relative ecological impact of individual agents on overall stand ecology. In contrast, the ranking maps are useful for identifying those watersheds with the greatest BA losses due to each mortality agent, regardless of how much BA loss is attributed to each pest or pathogen. For example, while the classification map clearly shows that mountain pine beetle is a much more wide-ranging and devastating tree-mortality agent than sires woodwasp, the ranking maps make it easy for the user to identify the watersheds where risk of mortality from each agent is greatest.

The classification maps are calculated by summing the BA loss for each risk agent and the total BA for all tree species in every watershed. The summed BA loss by risk agent is then divided by the total BA to determine the proportion of total BA that may be lost over the next 15 years. Proportions are then grouped within five categories: Host extent but little or no BA loss, 1–4% loss, 5–14% loss, 15–24% loss, and 25–100% loss.

The ranking maps are calculated by summing the BA loss for each risk agent in every watershed. Watersheds with a total of 1 square foot or less of BA loss (per watershed) are set to zero to eliminate noise in the final maps. All watersheds are then grouped and ranked into 100 BA loss classes through an equal-area stretch. The equal-area stretch assigns each watershed to a BA loss class and ensures that a nearly equal number of watersheds occupy each class. Watersheds are assigned to only one of the 100 classes and are not split among classes. Depending upon watershed size, some classes may contain slightly more area than other classes. Finally, the 100 classes are grouped into five categories based on their ranking in the BA loss distribution: Host present with > 5 square feet of BA host loss, the 49% least impacted watersheds, 50%–74%, 75%–95%, and the top 5% of most severely impacted watersheds.

The CHARTS presented in the Atlas (page 75) show, by risk agent, the BA loss rate of the most severely impacted watersheds on the ranking maps (i.e., the top 5% category). The ranking maps appear similar in that they depict the same amount of area in each impact category regardless of the agent’s absolute mortality level. Accordingly, we include a minimized version of this chart on all ranking maps to provide context about the overall impact of each pest or pathogen.

The Great Plains and its adjacent prairies are lightly forested. When depicted on national maps, it is difficult to differentiate between rankings of the most severely impacted areas and watersheds with little or no loss. Therefore, several key pests projected to impact treed areas of the Great Plains were re-mapped so as to restrict the rankings to only those watersheds within the Great Plains and adjacent prairie ecosystems.

Basal area estimates were not calculated for Hawaii. Instead, pest and pathogen maps for Hawaii are presented using 30-meter resolution cells that represent areas at risk due to each agent.
71.7 MILLION ACRES AT RISK IN THE COTERMINOUS UNITED STATES
**Percentage of Tree Area at Risk by Watershed**

- Little to no risk
- 1–4%
- 5–14%
- 15–24%
- 25% or greater
Watersheds Ranked by Basal Area Loss Hazard

- Host extent (little to no BA loss)
- Bottom 49%
- 50–74%
- 75–95%
- Top 5% – highest estimated BA losses
### Criteria Used to Model Risk Agents and Their Importance in Model Inputs

<table>
<thead>
<tr>
<th># of Models</th>
<th>Tree Species Parameters</th>
<th>Diameter</th>
<th>Basal Area/ Density</th>
<th>Host Presence</th>
<th>Climate</th>
<th>Proximity to Infestation</th>
<th>Physiographic</th>
<th>Other</th>
<th>Max. Mort. Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>186</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

#### ALASKA
- 1. Dendroctonus pseudotsugae mod 3 mod 1 mod 1 mod 2 mod 2 5-10
- 2. Ips grandis mod 1 mod 1 mod 1 30-50
- 3. Dendroctonus pseudotsugae mod 1 mod 1 mod 1 mod 1 25-30
- 4. Dendroctonus pseudotsugae mod 1 mod 1 mod 1 mod 1 25-30
- 5. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30

#### WEST
- 1. Sirex noctiluca mod 1 mod 1 mod 1 mod 1 15-20
- 2. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30
- 3. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30
- 4. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30
- 5. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30

#### NORTHEASTERN AREA
- 1. Asian longhorned beetle mod 1 mod 1 mod 1 mod 1 15-20
- 2. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30
- 3. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30
- 4. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30
- 5. Ips grandis mod 1 mod 1 mod 1 mod 1 25-30

#### CRITERIA USED TO MODEL RISK AGENTS AND THEIR IMPORTANCE IN MODEL INPUTS

<table>
<thead>
<tr>
<th>Weight Class</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>0-15%</td>
</tr>
<tr>
<td>mod</td>
<td>&gt;15-30%</td>
</tr>
<tr>
<td>high</td>
<td>&gt;30-40%</td>
</tr>
<tr>
<td>very high</td>
<td>&gt;45-60%</td>
</tr>
<tr>
<td>extremely high</td>
<td>&gt;60%</td>
</tr>
</tbody>
</table>

*See footnote, page 73.*
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<table>
<thead>
<tr>
<th>Agent</th>
<th>Modeled Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian longhorned beetle</td>
<td>Red maple and sugar maple</td>
</tr>
<tr>
<td>Apsen and cottonwood decline</td>
<td>Cottonwood species and quaking aper</td>
</tr>
<tr>
<td>Balsam woolly adelgid</td>
<td>Balsam, grand, pacific silver and subalpine fir</td>
</tr>
<tr>
<td>Beech bark disease</td>
<td>American beech</td>
</tr>
<tr>
<td>Bur oak blight</td>
<td>Bur oak</td>
</tr>
<tr>
<td>Douglas-fir beetle</td>
<td>Douglas-fir</td>
</tr>
<tr>
<td>Douglas-fir tussock moth</td>
<td>Douglas-fir, grand fir, and white fir</td>
</tr>
<tr>
<td>Dutch elm disease</td>
<td>American elm</td>
</tr>
<tr>
<td>Dwarf mistletoes</td>
<td>Douglas-fir, western larch, western hemlock, and the following pines: lodgepole, limber, ponderosa, tamarack and Arizona pinyon</td>
</tr>
<tr>
<td>Eastern larch beetle</td>
<td>Tamarack (native)</td>
</tr>
<tr>
<td>Eastern spruce budworm</td>
<td>Balsam fir and spruce species</td>
</tr>
<tr>
<td>Emerald ash borer</td>
<td>Ash species</td>
</tr>
<tr>
<td>Engraver beetle (Ips spp.)</td>
<td>White spruce and the following pines: eastern white, loblolly, longleaf, pitch pine, shortleaf, slash, Virginia, tamarack and Arizona pinyon</td>
</tr>
<tr>
<td>Erthyna gall wasp</td>
<td>Willow</td>
</tr>
<tr>
<td>Fij engraver</td>
<td>California red fir and grand/white fir species</td>
</tr>
<tr>
<td>Forest tent caterpillar</td>
<td>Aspen species</td>
</tr>
<tr>
<td>Fusiform rust</td>
<td>Slash pine and loblolly pine</td>
</tr>
<tr>
<td>Gold spotted oak borer</td>
<td>California black oak, California live oak, and canyon live oak</td>
</tr>
<tr>
<td>Hemlock woolly adelgid</td>
<td>Eastern hemlock and Carolina hemlock</td>
</tr>
<tr>
<td>Jack pine budworm</td>
<td>Jack pine</td>
</tr>
<tr>
<td>Jeffrey pine beetle</td>
<td>Jeffrey pine</td>
</tr>
<tr>
<td>Koush</td>
<td>Koush</td>
</tr>
<tr>
<td>Laurel wilt</td>
<td>Redbay and sassafras</td>
</tr>
<tr>
<td>Maple decline</td>
<td>Sugar maple</td>
</tr>
<tr>
<td>Mountain pine beetle</td>
<td>Limber, lodgepole, ponderosa, southwestern white, sugar, western white, and whitebark pines</td>
</tr>
<tr>
<td>Myoporum thrips</td>
<td>None</td>
</tr>
<tr>
<td>Oak decline and gypsy moth</td>
<td>Red oak and white oak species</td>
</tr>
<tr>
<td>Oak wilt</td>
<td>Live oak and red oak species</td>
</tr>
<tr>
<td>Olive rust</td>
<td>Olive</td>
</tr>
<tr>
<td>Root diseases, all</td>
<td>Spruce and fir species, Douglas-fir, mountain hemlock, Port-Orford-cedar, paper birch, western red cedar, and eastern white, jack, Jeffrey, longleaf, ponderosa, red, shortleaf, slash, and loblolly pines</td>
</tr>
<tr>
<td>Roundhead pine beetle</td>
<td>Ponderosa pine</td>
</tr>
<tr>
<td>Sirex wood wasp</td>
<td>Shortleaf, slash, pitch, ponder, Virginia, jack, red, longleaf, loblolly and Scotch pines</td>
</tr>
<tr>
<td>Southern pine beetle</td>
<td>Eastern white, longleaf, shortleaf, slash, loblolly, pitch, ponder, and Virginia pines</td>
</tr>
<tr>
<td>Spruce aphid</td>
<td>Sitka spruce</td>
</tr>
<tr>
<td>Spruce beetle</td>
<td>Engelmann, Sitka, and white spruces</td>
</tr>
<tr>
<td>Stem rust</td>
<td>Sitka spruce and western hemlock</td>
</tr>
<tr>
<td>Sudden oak death</td>
<td>California black oak, California live oak, and tamarack</td>
</tr>
<tr>
<td>Western gall wasp beetle</td>
<td>Subalpine fir</td>
</tr>
<tr>
<td>Western pine beetle</td>
<td>Coulter and ponderosa pines</td>
</tr>
<tr>
<td>Western spruce budworm</td>
<td>Engelmann spruce, Douglas-fir, grand fir, subalpine fir, and white fir</td>
</tr>
<tr>
<td>White pine blister rust</td>
<td>Eastern white, limber, Rocky Mountain bristlecone, southwestern white, sugar, western white, and whitebark pines</td>
</tr>
<tr>
<td>Winter moth</td>
<td>Oak species</td>
</tr>
<tr>
<td>Yellow-cedar decline</td>
<td>Alaska yellow-cedar</td>
</tr>
</tbody>
</table>

### Basal Area Loss Rates in Watersheds Most Impacted by Each Agent

*Group includes American, Douglas-fir, hemlock, larch, limber pine, pineal and ponderosa dwarf mistletoes.*

*Group includes Arizona-feathered Ips, eastern feathered Ips, northern spruce engraver, pine engraver, pinon Ips, Ips sosroandi, small southern pine engraver and three western species without common names; Ips latidens, Ips knausi and Ips integer.*

*Group includes armored, ambulatory, laminated root rot, and Port-Orford-cedar root diseases.*
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**Ohia Rust** *Puccinia psidii*

*Modeled host: ohia*

Ohia rust was first detected in Hawaii in 2005. The rust occurs on all the major islands and affects many native and non-native plants in the Myrtaceae family. The rust infects new foliage, and in some hosts the reproductive tissue and green stems. Ohia (*Metrosideros polymorpha*) is an endemic tree that makes up most of the remaining native forest in Hawaii and is mildly susceptible to the rust.

**Koa Wilt** *Fusarium oxysporum f. sp. koae*

*Modeled host: koa*

Koa wilt has been found on Hawaii (Big Island), Maui, Oahu, and Kauai. This vascular wilt disease is caused by a fungus that is now commonly found in soils of the Hawaiian Islands and can kill trees of all ages. The fungal pathogen enters the roots and then colonizes the main stem's conductive tissue, resulting in yellowing of leaves and crown wilt. Many plantation failures and high mortality rates of young trees have been observed.

**Myoporum Thrips** *Klambothrips myopori*

*Modeled host: naio*

The initial infestation of naio, a native, ecologically important species, by myoporum thrips in Hawaii was reported in 2009. Surveys are ongoing to determine its extent. This thrips causes leaf curling and gall-like symptoms on infected plants, with high levels of infestation resulting in plant mortality. The loss of naio would be particularly detrimental where it is a critical habitat component for the palila, *Loxioides bailleui*, a federally endangered species of honeycreeper on Mauna Kea.

**Erythrina Gall Wasp** *Quadristichus erythrinae*

*Modeled host: wiliwili*

The erythrina gall wasp was first detected on Oahu in 2005. Once introduced to Hawaii, the wasp spread across all of the main islands, resulting in chronic defoliation and mortality of thousands of endemic wiliwili, *Erythrina sandwicensis*, an important tree species in Hawaii's remaining lowland dry forests recognized as one of the most endangered habitats in Hawaii. Plant vigor declines from sequential defoliation and mortality may be observed in one to two years.
The Asian longhorned beetle is an introduced, destructive, wood-boring pest of maple and other hardwoods. The beetle was first discovered in the United States on trees in Brooklyn, New York, in 1996. Populations now exist in Massachusetts, New Jersey, New York, and Ohio.

Host extent:
- Little to no BA loss: <0.5%
- 1–4%
- 5–14%
- 15–24%
- 25% or greater of total BA loss

Host extent (little to no BA loss) ranked by basal area loss hazard:
- Bottom 49%
- 50–74%
- 75–95%
- Top 5%–highest estimated BA losses
In various ecosystems in the western United States and Great Plains, aspen and cottonwood stands are declining at an alarming rate. Stem longevity and the associated pathological rotation age seem to be getting shorter. While we know cottonwood and aspen to be short-lived, stand decline seems to be occurring at an increasingly younger stand age. Pest complexes seem to be changing, with the worst impact on hottest and driest areas: low-lying, south-facing slopes.
In various ecosystems in the western United States and Great Plains, aspen and cottonwood stands are declining at an alarming rate. Stem longevity and the associated pathological rotation age seem to be getting shorter. While we know cottonwood and aspen to be short-lived, stand decline seems to be occurring at an increasingly younger stand age. Pest complexes seem to be changing, with the worst impact on hottest and driest areas: low-lying, south-facing slopes.

**Host extent (little to no BA loss)**
- 1–4%
- 5–14%
- 15–24%
- 25% or greater of total BA loss

William M. Ciesla
The balsam woolly adelgid is a tiny sucking insect that was introduced into North America from Europe in the mid-1950s. True firs in the United States have no natural defenses against this pest. In some areas, infestations have been so high, true firs have been eliminated entirely from the infested areas.

**BALSAM WOOLLY ADELGID**  *Adelges piceae*

**Modeled hosts:** balsam fir, grand fir, pacific silver fir, and subalpine fir

The balsam woolly adelgid is a tiny sucking insect that was introduced into North America from Europe in the mid-1950s. True firs in the United States have no natural defenses against this pest. In some areas, infestations have been so high, true firs have been eliminated entirely from the infested areas.
The balsam woolly adelgid is a tiny sucking insect that was introduced into North America from Europe in the mid-1950s. True firs in the United States have no natural defenses against this pest. In some areas, infestations have been so high, true firs have been eliminated entirely from the infested areas.

**Balsam woolly adelgid** *Adelges piceae*

**Modeled hosts:** balsam fir, grand fir, pacific silver fir, and subalpine fir

*Host extent* (little to no BA loss)
- Bottom 49%
- 50–74%
- 75–95%
- Top 5%—highest estimated BA losses
**Beech Bark Disease** *Nectria faginata*

**Modeled host:** American beech

In the United States, this disease results when the beech scale insect attacks the bark of beech, allowing the introduction of two species of fungi to invade the tree through the wound and cause a canker to be formed. As cankers continue to form, death of the tree can result.
**Bur oak blight** *Tabakia iowensis*

**Modeled host:** bur oak

As a leafspot fungus that occurs only on bur oaks, this relatively new pest of the upper Midwest is associated with early spring rainfall and has been reported since the early 1990s. It is not clear if the pathogen is a recent arrival, or if a shift in climate has made this disease more noticeable.
bur oak blight — Great Plains *Tabakia iowensis*

Modeled host: bur oak

As a leafspot fungus that occurs only on bur oaks, this relatively new pest of the upper Midwest. It is associated with early spring rainfall and has been reported since the early 1990s. It is not clear if the pathogen is a recent arrival, or if a shift in climate has made this disease more noticeable.

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<tbody>
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<td>50–74%</td>
<td>75–95%</td>
<td>Top 5%—Highest estimated BA losses</td>
<td></td>
</tr>
</tbody>
</table>
Douglas-fir beetle, *Dendroctonus pseudotsugae*

**Modeled host:** Douglas-fir

Douglas-fir beetle is the single most important bark beetle enemy of Douglas-fir. When outbreaks occur, this beetle can kill thousands of seemingly healthy Douglas-fir trees. During outbreaks, groups of trees, ranging from a few to several hundred, can be affected.

### Percentage of Total Basal Area Loss by Watershed

- **Host extent (little to no BA loss):** 1–4%
- **5–14%**
- **15–24%**
- **25% or greater of total BA loss**

### Watersheds Ranked by Basal Area Loss Hazard

- **Host extent (little to no BA loss):** Bottom 49%
- **50–74%**
- **75–95%**
- **Top 5%–highest estimated BA losses**
**Douglas-fir tussock moth** *Orgyia pseudotsugata*

**Modeled hosts:** Douglas-fir, grand fir, and white fir

The Douglas-fir tussock moth is an important defoliator of true firs, spruces, and Douglas-fir in western North America. Insect outbreaks occur rather suddenly; therefore, considerable effort is made to monitor this insect through the use of a west-wide system of pheromone traps.

**Percentage of Total Basal Area Loss by Watershed**

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Dutch elm disease is one of the most destructive shade tree diseases in North America. The disease affects American elms—and other elm species to a lesser extent—killing individual branches and, eventually, the entire tree within one to three years.

Host extent (little to no BA loss)
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- 5–14%
- 15–24%
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Watersheds ranked by basal area loss hazard
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Dutch elm disease is one of the most destructive shade tree diseases in North America. The disease affects American elms—and other elm species to a lesser extent—killing individual branches and, eventually, the entire tree within one to three years.

**Modeled host:** American elm

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- 15–24%
- 25% or greater of total BA loss

**Watersheds ranked by BA loss hazard**
- Host extent (little to no BA loss)
- Bottom 49%
- 50–74%
- 75–95%
- Top 5%—Highest estimated BA losses
Dwarf mistletoes are the most important vascular plant parasites of conifers in the United States. These shrubby, aerial parasites are dispersed by birds or by seed dispersion through explosive fruits. Dwarf mistletoes are obligate parasites, dependent on their host for water, nutrients, and some or most of their food. Pathogenic effects on the host include deformation of the infected stem, growth loss, and increased susceptibility to other pests.
Dwarf mistletoes *Arceuthobium* spp.

**Modeled hosts:** Douglas-fir, western larch, western hemlock, lodgepole pine, limber pine, pinyon pine, and ponderosa pine.

Dwarf mistletoes are the most important vascular plant parasites of conifers in the United States. These shrubby, aerial parasites are dispersed by birds or by seed dispersion through explosive fruits. Dwarf mistletoes are obligate parasites, dependent on their host for water, nutrients, and some or most of their food. Pathogenic effects on the host include deformation of the infected stem, growth loss, and increased susceptibility to other pests.
The eastern larch beetle is a native North American insect that colonizes the phloem of the main stem, exposed roots, and larger branches of tamarack, or eastern larch. Extensive tree mortality has been reported throughout the range of eastern larch, and beetle outbreaks have been reported from the late 1800s.
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The eastern spruce budworm is one of the most destructive native forest defoliators and is responsible for shaping the stand composition and structure of northern spruce and fir forests in the eastern United States and Canada.
EmEralD Ash BorEr  *Agrilus planipennis*

**Modeled hosts:** ash species

Uniquely a tree-killer in the United States, the emerald ash borer is by far the most destructive invasive exotic species to have arrived in North America in quite some time.
**Emerald Ash Borer** *Agrilus planipennis*

**Modeled hosts:** ash species

Unequivocally a tree-killer in the United States, the emerald ash borer is by far the most destructive invasive exotic species to have arrived in North America in quite some time.
EmErald ash borEr — Great Plains  
*Agrilus planipennis*

Modeled host: ash species

Unequivocally a tree-killer in the United States, the emerald ash borer is by far the most destructive invasive exotic species to have arrived in North America in quite some time.

**Percentage of Total Basal Area Loss by Watershed**

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**Watersheds Ranked by Basal Area Loss Hazard**

- Host extent (little to no BA loss)
- Bottom 49%
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- 75–95%
- Top 5%—Highest estimated BA losses
Engraver beetles *Ips* spp.

**Modeled hosts:** white spruce and the following pines: pinyon, ponderosa, shortleaf, slash, longleaf, loblolly, pitch, pond, Virginia, and eastern white

Engraver beetles belong to the *Ips* genus of beetles. These beetles are very common throughout the United States, though they only contribute to significant pine tree mortality during periods of drought or other environmental stress.

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**Fir engraver  *Scolytus ventralis***

*Modeled hosts:* California red fir and grand/white fir species

Fir engravers are tree-killers of true firs, usually attacking pole-sized to saw-timber sized trees. Outbreaks are associated with drought and the presence of root diseases.

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**Percentage of Total Basal Area Loss by Watershed**

- Host extent (little to no BA loss)
- 1–4%
- 5–14%
- 15–24%
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---

**Watersheds Ranked by Basal Area Loss Hazard**

- Host extent (little to no BA loss)
- Bottom 49%
- 50–74%
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- Top 5%–highest estimated BA losses
Forest tent caterpillar *Malacosoma disstria*

**Modeled hosts:** aspen species

The forest tent caterpillar is native and may be found throughout the United States and Canada wherever hardwoods grow—from the Pacific Northwest to the South and the upper Midwest, and along the mid-Atlantic states to New England. The favored hosts of this insect are sugar maple, aspen, oaks, water tupelo, sweetgum, blackgum, cottonwood, elms, red alder, and willow.
Fusiform rust *Cronartium quercuum*

**Modeled hosts:** slash pine and loblolly pine

Fusiform rust is a fungus that causes swellings, called galls, on branches and stems of pines. Mortality is greatest on young trees, but the rust galls and cankers deform and weaken older trees as well. The pathogen requires both pine and oak to complete its life cycle.
The goldspotted oak borer is native to oak forests of southeastern Arizona, and a closely related species is found in Central America. Since 2002, the borer is associated with the death of more than 80,000 trees, and this infested area continues to expand as borer populations grow and spread. The borer is not a pest in its native range.
Few pests other than chestnut blight and Dutch elm disease have had such a marked effect on eastern forests. Left unchecked, the hemlock woolly adelgid will likely extirpate most of the native hemlock from eastern North America.

**Host extent (little to no BA loss)**
- 1–4%
- 5–14%
- 15–24%
- 25% or greater of total BA loss

**Watersheds ranked by basal area loss hazard**

**Percentage of total basal area loss by watershed**
Jack pine budworm is a needle-feeding caterpillar and considered to be the most significant pest of jack pine. Stands older than 45 years, that are growing on very sandy sites and suffering from drought or other stresses, are very vulnerable to damage. Topkill and, ultimately, mortality result when stressed trees are attacked.
**Jeffrey Pine Beetle** *Dendroctonus jeffreyi*

**Modeled host:** Jeffrey pine

The Jeffrey pine beetle kills trees by mining between bark and wood and is the principal bark-beetle enemy of Jeffrey pine. The beetle has economic impacts chiefly in California; it is most destructive in older stands in the timber-producing areas of northeastern California.
Laurel wilt  *Raffaelea lauricola*

**Modeled hosts:** redbay and sassafras

Laurel wilt is a deadly disease of redbay and other tree species in the Laurel family, such as avocado. The disease is caused by a fungus introduced into host trees by the redbay ambrosia beetle (*Xyleborus glabratus*), a non-native insect. This disease is expected to extirpate redbay from southern forests.
Maple decline

Modeled host: sugar maple

More sporadic and less extensive than oak decline, maple decline is associated with drought and harsh site or exposed conditions. Symptoms include slowed radial growth, crown dieback, attack by secondary organisms, and tree mortality.
The mountain pine beetle is the most important biotic change agent in western forests. This insect has been responsible for contributing to the death of many millions of acres of trees in lodgepole and ponderosa pine forests.

**Host extent**
- (little to no BA loss)
- 1–4%
- 5–14%
- 15–24%
- 25% or greater of total BA loss

**Watersheds ranked by basal area loss hazard**
- Most extent (little to no BA loss)
- Bottom 49%
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- 75–95%
- Top 5%--highest estimated BA losses
Oak decline and gypsy moth

Host extent:
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- 25% or greater of total BA loss

Host extent (little to no BA loss)
- Bottom 49%
- 50–74%
- 75–95%
- Top 5%–highest estimated BA losses

Modeled hosts: red oak and white oak species

Periods of local and regional occurrences of oak decline have been reported since the early 1900s. Trees weakened from environmental stresses, such as drought, phloem feeders, root pathogens, sucking insects, and defoliators (notably gypsy moth), experience reduced annual growth, canopy dieback, and death.
Periods of local and regional occurrences of oak decline have been reported since the early 1900s. Trees weakened from environmental stresses, such as drought, phloem feeders, root pathogens, sucking insects, and defoliators (notably gypsy moth), experience reduced annual growth, canopy dieback, and death.
Oak wilt is a vascular disease of oak that can quickly kill a tree. It is caused by the fungus *Ceratocystis fagacearum*. Symptoms vary by tree species but generally consist of leaf discoloration, wilt, defoliation, and death. This fungus spreads overland on the various insect species that fly to surface wounds or through underground root grafting.

Modeled hosts: live oak and red oak species
Root diseases are the most damaging group of diseases affecting forest trees in the United States. Root diseases kill trees, decay wood, slow tree growth, predispose trees to other risk agents, and cause trees to fail or fall over. They impact timber volume, forest composition and structure, ecosystem function, personal safety, and carbon sequestration.

**Host extent (little to no BA loss)**

- 1–4%
- 5–14%
- 15–24%
- 25% or greater of total BA loss

**Modeled hosts:** spruce and fir species, Douglas-fir, mountain hemlock, Port-Oriole-cedar, paper birch, western red cedar, and the following pines: eastern white, jack, jeffrey, longleaf, ponderosa, red, shortleaf, slash, and loblolly.
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**Roundheaded Pine Beetle** *Dendroctonus adjunctus*

**Modeled host:** ponderosa pine

This pine pest attacks ponderosa pine, primarily in the southwestern United States. Outbreaks of this beetle, at least in the recent past, are short-lived and sporadic. Damage is typically found on ridgetops and other sites with very dry, sandy soils.

### Host extent (little to no BA loss)
- 1–4%
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### Watersheds ranked by basal area loss hazard
- 2%
- Bottom 49%
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- Top 5%–highest estimated BA losses
**Sirex woodwasp** *Sirex noctilio*

**Modeled hosts:** shortleaf, slash, longleaf, loblolly, pitch, pond, Virginia, jack, red, and Scotch pines

The *Sirex woodwasp* is a species of horntail native to Europe, Asia, and northern Africa. This invasive species is established in many parts of the world, including Australia, New Zealand, North America, South America, and South Africa, where it can become a significant economic pest of pine. The wasps can attack a wide variety of pine tree species, and stressed trees are those most often attacked.
The southern pine beetle is the most destructive bark beetle in the eastern United States. Intensively managed forests and active prevention programs have minimized the impact of this potentially explosive pest.
Spruce Aphid  *Elatobium abietinum*

**Modeled host:** Sitka spruce

The spruce aphid is thought to have been introduced to North America from Europe. Sitka, Norway, and blue spruce are preferred hosts, but other spruce species might also be attacked.
**Spruce Beetle** *Dendroctonus rufipennis*

**Modeled hosts:** Engelmann spruce, Sitka spruce, and white spruce

The spruce beetle is the most significant biotic disturbance agent of mature spruce. Outbreaks of spruce beetles have dramatically changed the structure and composition of North American spruce forests.

Percentage of total basal area loss by watershed:

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Stem rot

Modeled hosts: Sitka spruce and western hemlock

Stem rot fungi have a major impact on the forests of Southeast Alaska, where roughly a third of the old-growth timber volume of live trees is affected. These fungi predispose large old trees to bole breakage. Small-scale canopy gaps created by individual tree mortality events serve important ecological functions.
Sudden oak death  *Phytophthora ramorum*

**Modeled hosts:** California black oak, California live oak, and tanoak

Sudden oak death is a tree disease caused by the pathogen *Phytophthora ramorum*. The disease kills some oak species and tanoak, and has had significant effects on forests in California and Oregon.
The western balsam bark beetle is the most conspicuous of a complex of pests which are responsible for high rates of tree mortality in sub-alpine fir stands from New Mexico and Arizona through the northern Rocky Mountains. Typically, infestations are chronic, contributing to high rates of subalpine fir mortality in the West.
Western pine beetle *Dendroctonus brevicomis*

**Modelled hosts:** Coulter pine and ponderosa pine

Western pine beetle can be found throughout most of the native range of ponderosa pine and Coulter pine in California. As with most *Dendroctonus* beetles, this pest breeds in larger trees or in trees that have been stressed by drought, disease, fire, or overly dense conditions.
The western spruce budworm is one of the most destructive forest defoliators in western North America. Outbreaks have occurred from the central Rockies in the United States to the Coast Mountains in British Columbia, Canada, and the panhandle of Alaska.
White pine blister rust *Cronartium ribicola*

**Modeled hosts:** eastern white, limber, Rocky Mountain bristlecone, southwestern white, sugar, western white, and whitebark pine.

White pine blister rust is probably the most destructive disease of five-needle pines in North America and is a major threat to high-elevation white pines in the western United States. The pathogen is believed to have originated in Asia. By the 1960s it had spread to most of the commercial white pine regions. It became established in Europe as well, after large numbers of highly susceptible American white pines were imported and planted there.
White pine blister rust  *Cronartium ribicola*

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**Winter moth** *Operophtera brumata*

*Modeled hosts: oak species*

Winter moth is an insect pest that was introduced to North America from Europe. It is now established in eastern Canada, British Columbia, New England, and the Pacific Northwest. Various deciduous trees are susceptible, including oaks, maples, basswood, ash, crabapples, apple, blueberry, and certain spruces. Multiple defoliations or interactions with other stressors can lead to tree death.
**YELLOW-CEDAR DECLINE**

*Modeled host: Alaska yellow-cedar*

Yellow-cedar decline is not well-understood, but is thought to be associated with root freezing that occurs during very cold weather when the ground is not insulated with snow.
Emerald ash borer

49 Steven Katochik, USDA Forest Service

Emerald ash borer

Damage–Ash killed by EAB in southeastern Michigan

Pennsylvania Department of Conservation and Natural Resources–Bugwood.org

Emerald ash borer adult

114 Pennsylvania Department of Conservation and Natural Resources–Forestry Archive, Bugwood.org

Emerald ash borer adult

115 Edward Cervenka, Ontario Ministry of Natural Resources, Bugwood.org

Emerald ash borer

116 Delisle Miller, USDA Forest Service, Bugwood.org

Emerald ash borer adult feeding on an ash leaf

117 Pennsylvania Department of Conservation and Natural Resources–Forestry Archive, Bugwood.org

Larva(s)

118 Brian Sullivan, USDA APHIS PPQ, Bugwood.org

Adult–Emerald ash borer

119 Christopher Asan, Virginia Department of Forestry, Bugwood.org

Galleries

120 Joseph Brien, USDA Forest Service, Bugwood.org

Damage–Trees removed after infestation

121 William M. Ciesla, Forest Health Management International, Bugwood.org

Emerald ash borer mortality. Photo taken August 2013

122 Art Wagner, USDA APHIS, Bugwood.org

Galleries

123 Christopher Asan, Virginia Department of Forestry, Bugwood.org

Damage

124 Kenneth R. Law, USDA APHIS PPQ, Bugwood.org

Emergover beetle (ips spp.)

125 A. Steven Munsie, USDA Forest Service, Bugwood.org

Prony (ips adults)

126 Dave Powell, USDA Forest Service, Bugwood.org

Ips emerald beetle damage

127 Roger Anderson, Duke University, Bugwood.org

Eastern firequeen Ips Leighana, pupa, and young callow adult

128 Tie Smith, Bugwood.org

Prony Ips damage

129 William M. Ciesla, Forest Health Management International, Bugwood.org

Aerial view of scattered tree mortality in a young pine plantation

130 USDA Forest Service–San Diego Co., California, Bugwood.org

Adult–Emerald ash borer beetle

131 Ronald F. Billings, Texas Forest Service, Bugwood.org

On fallen pines or on pine logs, the accumulations of red or brown sawdust on the surface of the bark are another sign of attacks by secondary bark beetles (ips spp.)

132 Ronald F. Billings, Texas Forest Service, Bugwood.org

Infestation–Infested with Ips and black turpentine beetles

133 G. Keith Drexler, University of Georgia, Bugwood.org

Galleries–With adults and damage

134 William M. Ciesla, Forest Health Management International, Bugwood.org

Damage–Top kill caused by pine engraver beetle in Pinus sylvestris var. hémistico, near Bangkok

135 Edward H. Holsten, USDA Forest Service, Bugwood.org

Adult–Northern spruce engraver

136 Edward H. Holsten, USDA Forest Service, Bugwood.org

Galleries

137 Edward H. Holsten, USDA Forest Service, Bugwood.org

Infestation–White spruce mortality

138 Edward H. Holsten, USDA Forest Service, Bugwood.org

Damage–Frass on bark

Ertryhna gall wasp

79 Shant Smith, USDA Forest Service

Damage

Fe engraver

120 USDA Forest Service–San Diego Co., California, Bugwood.org

Infestation

121 Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org

Adult–Fe engraver

122 Dave Powell, USDA Forest Service, Bugwood.org

Damage–Ibred foliage stage. Malheur National Forest, northeastern Oregon

123 Fred Horig, USDA Forest Service, Bugwood.org

Horizontal gall–trees

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### Laurel wilt, continued

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<td>R. Scott Cameron, Advanced Forest Protection, Inc., Bugwood.org</td>
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### Maple decline

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### Mountain pine beetle

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### Myrrh tree

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<td>University of California Riverside Center for invasive species research</td>
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### Oak decline and gypsy moth

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### Root diseases—all

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<td>Robert L. James, USDA Forest Service, Bugwood.org</td>
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<td>153</td>
<td>Andrey Kunca, National Forest Centre—Slovakia, Bugwood.org</td>
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<td>153</td>
<td>USDA Forest Service Archive, USDA Forest Service, Bugwood.org</td>
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### Root diseases, continued

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<td>153</td>
<td>Cathy Stewart, USDA Forest Service, Bugwood.org</td>
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<td>Robert L. Anderson, USDA Forest Service, Bugwood.org</td>
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<td>John W. Schiendal, USDA Forest Service, Bugwood.org</td>
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<td>154</td>
<td>James W. Byler, USDA Forest Service, Bugwood.org</td>
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<td>155</td>
<td>Susan K. Hogle, USDA Forest Service, Bugwood.org</td>
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### Roundheaded pine beetle

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<td>Steven Valley, Oregon Department of Agriculture, Bugwood.org</td>
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### Srax woodwasp

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<td>158</td>
<td>William M. Ciesla, Forest Health Management International, Bugwood.org</td>
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<td>159</td>
<td>Dennis Haugen, Bugwood.org</td>
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<td>159</td>
<td>David R. Larsen, USDA APHIS PPQ, Bugwood.org</td>
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<td>159</td>
<td>Vicky Klasmer, Instituto Nacional de Tecnologia Agropecuaria, Bugwood.org</td>
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### Southern pine beetle

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<td>160</td>
<td>Ronald F. Billings, Texas Forest Service, Bugwood.org</td>
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<td>Ronald F. Billings, Texas Forest Service, Bugwood.org</td>
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<td>161</td>
<td>Erin G. Valley, USDA Forest Service—SRS-4552, Bugwood.org</td>
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<td>Ronald F. Billings, Texas Forest Service, Bugwood.org</td>
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### Spruce aphid

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<td>163</td>
<td>Jeff Whisen, USDA Forest Service, Bugwood.org</td>
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<td>163</td>
<td>Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org</td>
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<td>163</td>
<td>Petr Kapitola, State Phytopharmaceutical Administration, Bugwood.org</td>
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### Spruce beetle

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<td>165</td>
<td>Whitney Cramshau, Colorado State University, Bugwood.org</td>
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<td>166</td>
<td>Andrea Shilanty, USDA Forest Service, Bugwood.org</td>
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### Sudden oak death

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<td>168</td>
<td>Paul E. Hennon, USDA Forest Service, Bugwood.org</td>
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Photo Credits continued (photos shown in order of appearance from left to right)
Yellow-cedar decline

White pine blister rust

Western spruce budworm

Western pine beetle

Western balsam bark beetle

Yellow-cedar decline

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Photo Credits

193

Acronyms

193

APHIS PPQ Animal and Plant Health Inspection Service, Plant Protection and Quarantine

BA Bristol Area

BLM Bureau of Land Management

CART Classification and Regression Tree

CMIP3 Climate Model Intercomparison Project 3

DBH Diameter at Breast Height

DDT NIDRM’s Data Development Team

DI Soil Drainage Index

FHM Forest Health Monitoring

FHP Forest Health Protection

FHTET Forest Health Technology Enterprise Team

FIA Forest Inventory and Analysis

GIS Geographic Information System

IDW Inverse Distance Weighting

MAP Mean Annual Precipitation

MAT Mean Annual Temperature

MDT NIDRM’s Model Development Team

MODIS Moderate Resolution Imaging Spectroradiometer

NDVI Normalized Difference Vegetation Index

NIDRM National Insect and Disease Risk Map

NA Northeast Area (Forest Service: State and Private administrative unit for northeastern states)

NLCD National Land Cover Data

NOAA National Oceanic and Atmospheric Association

NOAA-NCCDC National Oceanic and Atmospheric Association National Climate Data Center

NCRS Natural Resources Conservation Service

PET Potential Evapotranspiration

PI Productivity Index

PRISM Parameter-elevation Regressions on Independent Slopes Model

QMD Quadratic Mean Diameter

R1 Region 1 of U.S. Forest Service. (This convention is used for other Forest Service regions; e.g. R8 for Region 8)

RMAP Risk Modeling Application

RMOT Risk Map Oversight Team

RSAC Remote Sensing Applications Center

SDI Stand Density Index

SDEL Spatial Data Library (Maintained by FHTET)

STATSGO2 State Soil Geographic database

SSURGO Soil Survey Geographic Database

USDA United States Department of Agriculture

USDI United States Department of Interior

USGS United States Geological Survey

2013–2027 National Insect and Disease Forest Risk Assessment

2013–2027 National Insect and Disease Forest Risk Assessment