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 treed 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 rate(s) 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 mortality for the modeled agent that will be attributed to a pixel in the final maps. 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 rate 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 18 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. 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 into 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 5 square feet 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 occupies 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 categories labeled with < 5 square feet of BA host loss, the 49%–74% category, 75%–95%, and the top 5% of most severely impacted watersheds. These identify the watersheds where BA loss potential is greatest.

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 into five categories: Host extent but little or no BA loss, 1–4% loss, 5–14% loss, 15–24% loss, and 25–100% loss.

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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 A.1

| # of Models | # of Models |
|-------------|-------------|
| 23          | 23          |

### NORTHEASTERN AREA

| Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 2        |                     |                 |         |                          |       |            |       |                |
| 1        | Asian longhorned beetle |               |         |                          |       |            |       |                |
| 2        |                     |                 |         |                          |       |            |       |                |
| 1        | Balsam woolly adelgid | high 1          | high 1  |                          | high 1 |            |       |                |
| 2        |                     |                 |         |                          |       |            |       |                |
| 1        | Dutch elm disease | < high 1        | < high 1 |                          | high 1 |            |       |                |
| 2        |                     |                 |         |                          |       |            |       |                |

### INTERIOR WEST

| Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 3        |                     |                 |         |                          |       |            |       |                |
| 3        |                     |                 |         |                          |       |            |       |                |
| 2        |                     |                 |         |                          |       |            |       |                |
| 2        |                     |                 |         |                          |       |            |       |                |

### SOUTHWEST

| Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 1        |                     |                 |         |                          |       |            |       |                |
| 1        |                     |                 |         |                          |       |            |       |                |

### SOUTHEAST

| Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 1        |                     |                 |         |                          |       |            |       |                |
| 1        |                     |                 |         |                          |       |            |       |                |

### WILDERNESS

| Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 1        |                     |                 |         |                          |       |            |       |                |
| 1        |                     |                 |         |                          |       |            |       |                |

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

| # of Models | Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|-------------|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 23          |          |                     |                 |         |                          |       |            |       |                |

### Table 1

| Diameter | Basal Area/ Density | Host Prevalence | Climate | Proximity to Infestation | Soils | Topography | Other | Max. Mort. Rate |
|----------|---------------------|-----------------|---------|--------------------------|-------|------------|-------|----------------|
| 2        |                     |                 |         |                          |       |            |       |                |

| Weight Class | Weight |
|--------------|--------|
| low          | 0–15%  |
| mod          | >15–30%|
| high         | >30–40%|
| very high    | >45–60%|
| extremely high| >60%   |

*Criteria used as inputs to the risk models (see Methods section, and Table 1, page 4, therein) are classified according to the table’s column headings. The “Weights” reported here represent the average weight across models, given to the criteria in each region. For any one model, the sum of the weights equals 100%. Numerals according to this table’s column headings. The “Weights” reported here represent the average weight across models, given to the criteria in each region. For any one model, the sum of the weights equals 100%. Numerals according to this table’s column headings. The “Weights” reported here represent the average weight across models, given to the criteria in each region. For any one model, the sum of the weights equals 100%.*

*Maximum Mortality Rate is the range of maximum allowable host mortality rates across the suite of agent-specific models, by region. For maximum mortality rates by host/agent combination, see Table 5, page 18.*
Host Species Modeled for Each Agent

| Agent                          | Host Species Modelled for Each Agent |
|--------------------------------|--------------------------------------|
| Asian longhorned beetle        | Red maple and sugar maple            |
| Aspen and cottonwood decline   | Cottonwood species and quaking aspen |
| Balsam woolly adelgid          | Balsam, grand, pacific silver and subalpine fir |
| Beech bark disease             | American beech                       |
| Bur oak blight                 | Bur oak                              |
| Douglas-fir beetle             | Douglas-fir                          |
| Douglas-fir tussock moth       | Douglas-fir, grand fir, and white fir |
| Dutch elm disease              | American elm                         |
| Dwarf mistletoes 1             | Douglas-fir, western larch, western hemlock, and the following pines: lodgepole, limber, ponderosa, twoweedle pine, singleleaf pine, border pine, Mexican pine, and Arizona pine. |
| Eastern larch beetle           | Tamarack (native)                    |
| Eastern spruce budworm         | Balsam fir and spruce species        |
| Emerald ash borer              | Ash species                          |
| Engraver beetle (Ips spp.) 2   | White spruce and the following pines: eastern white, loblolly, longleaf, pitch, pod, shortleaf, slash, Virginia, twoweedle pine, singleleaf pine, border pine, Mexican pine, Arizona pine, and ponderosa. |
| Erythrina gall wasp            | Wisteria                             |
| Fir engraver                   | California red fir and grand/white fir species |
| Forest tent caterpillar        | Aspen species                        |
| Fusiform rust                  | Slash pine and loblolly pine         |
| Goldspotted oak borer          | California black oak, California live oak, and canyon live oak |
| Hemlock woolly adelgid         | Eastern hemlock and Carolina hemlock |
| Jack pine beetle               | Jack pine                            |
| Jeffrey pine beetle            | Jeffrey pine                         |
| Koa                            | Koa                                  |
| Laurel wilt                    | Redbud and suvasilas                |
| Maple decline                  | Sugar maple                          |
| Mountain pine borer            | Limber, lodgepole, ponderosa, southwestern white, sugar, western white, and whitebark pines |
| Myrothamn thepsi               | None                                 |
| Oak decline and lamina crispa  | Red oak and white oak species        |
| Oak wilt                       | Live oak and red oak species         |
| Olha rust                      | Olha                                 |
| Root diseases, all 1           | Spruce and fir species, Douglas-fir, mountain hemlock, Port-Orford-cedar, paper bark, western red cedar, and eastern white, jack, Jeffrey, longleaf, ponderosa, red, shortleaf, slash, and loblolly pines. |
| Roundheaded pine borer         | Ponderosa pine                       |
| Sirex woodwasp                 | Shortleaf, slash, pitch, pod, Virginia, jack, red, longleaf, loblolly and Scotch pines |
| Southern pine beetle           | Eastern white, longleaf, shortleaf, slash, loblolly, pitch, pod, and Virginia pines |
| Spruce aphid                   | Sitka spruce                         |
| Spruce beetle                  | Engelmann sitka and white spruces    |
| Stem rot                       | Sitka spruce and western hemlock     |
| Sudden oak death               | California black oak, California live oak, and tamarack |
| Western Balsam bark beetle     | Subalpine fir                        |
| Western pine beetle            | Coast and ponderosa pines            |
| Western spruce budworm         | Engelmann spruce, Douglas-fir, grand fir, subalpine fir, and white fir |
| White pine blower rust         | Eastern white, Limber, Rocky Mountain bristlecone, southwestern white, sugar, western white, and whitebark pines |
| Winter moth                    | Oak species                          |
| Yellow-cedar decline           | Alaska yellow-cedar                  |

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

2 Group includes Arizona five-spined Ips, eastern five-spined Ips, northern spruce engraver, pine engraver, pine Ips, Ips spined Ips, small southern pine engraver and three western species without common names: Ips latidens, Ips knausi and Ips integer.

3 Group includes arruosa, amillicola, laminated root rot, and Port-Orford-cedar root diseases.

Basal Area Loss Rates in Watersheds Most Impacted by Each Agent

A miniature version of these charts accompanies each of the following maps labelled, “Watershed Ranked by Basal Area Loss Hazard” (Hawaii and Great Plains maps excluded). In the miniature charts, the bar representing the agent depicted in the map is highlighted. The x-axis represents the average basal area mortality rate of the agent’s host tree species in the most severely impacted watersheds (top 5% category). See page 63 for details.
Risk Agents for Hawaii

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Koa wilt (fusarium oxysporum f. sp. koae) ............... 78
Myoporum thrips (Klambothrips myopori) ............ 79
Erythrina gall wasp (Quadristichus erythrinae) .... 79

Risk Agents for Alaska and the Coterminous United States

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Aspen and cottonwood decline .................................. 82
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Western spruce budworm (Choristoneura occidentalis) 176
White pine blister rust (Cronartium ribicola) ........ 178, 180
Winter moth (Operophtera brumata) ..................... 182
Yellow-cedar decline ....................................... 184
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 infested 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  *Quadrastichus 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.
**Asian longhorned beetle** *Anoplophora glabripennis*

*Modeled hosts:* red maple, sugar maple, and other hardwoods

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.

**Percentage of total basal area loss by watershed**

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

**Watersheds 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.
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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*

- **Host extent:** little to no BA loss, 1–4%, 5–14%, 15–24%, 25% or greater of total BA loss.
- **Modeled hosts:** balsam fir, grand fir, Pacific silver fir, and subalpine fir.
Balsam woolly adelgid *Adelges piceae*

**Modelled 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.

Ronald F. Billings
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**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
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  *Tubakia 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.
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.
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.
**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.

| Host extent (little to no BA loss) | 1–4% | 5–14% | 15–24% | 25% or greater of total BA loss |
|-----------------------------------|------|-------|--------|-------------------------------|
| Bottom 49%                        |      |       |        |                               |
| 50–74%                            |      |       |        |                               |
| 75–95%                            |      |       |        |                               |
| Top 5%–highest estimated BA losses|      |       |        |                               |
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

**Dutch Elm Disease** *Ophiostoma novo-ulmi*

- Host extent (little to no BA loss) 3%
- Bottom 49%
- 50–74%
- 75–95%
- Top 5%–highest estimated BA losses

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

**Watersheds Ranked by Basal Area Loss Hazard**
Dutch elm disease — Great Plains  
*Ophiostoma novo-ulmi*

**Modeled host:** American elm

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):** 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%
- **5–14%**
- **15–24%**
- **25% or greater of total BA loss**
**Dwarf Mistletoes — Alaska** *Arceuthobium* spp.

**Modeled host:** western hemlock

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.

**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
**Eastern Larch Beetle** *Dendroctonus simplex*

**Host extent:**
- 2%: Host extent (little to no BA loss)
- 1–4%: Bottom 49%
- 5–14%: 50–74%
- 15–24%: 75–95%
- 25% or greater of total BA loss: Top 5%–highest estimated BA losses

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.

**Modeled host:** tamarack (native)
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.
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.
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.

Host extent:
- Little to no BA loss
- Bottom 49%
- 50–74%
- 75–95%
- Top 5%–highest estimated BA losses
Percentage of Total Basal Area Loss by Watershed

Emerald Ash Borer — Great Plains

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.

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
**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.
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.

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

**Modeled hosts:** White spruce and the following pines: pinyon, ponderosa, shortleaf, slash, longleaf, loblolly, pitch, pond, Virginia, and eastern white.
Engraver beetle — Northern Spruce Engraver *Ips perturbatus*

**Modeled host:** white spruce

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

**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
**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, black gum, cottonwood, elms, red alder, and willow.

**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

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2013–2027 National Insect and Disease Forest Risk Assessment
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.
Hemlock woolly adelgid *Adelges tsugae*

**Modeled hosts:** eastern hemlock and Carolina hemlock

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.
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.

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

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

**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
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.

**Modeled hosts:** limber, lodgepole, ponderosa, southwestern white, sugar, western white, and whitebark pine

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.
Oak Decline and *Lymantria dispar dispar*

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 *lymantria dispar dispar*), 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 *lymantria dispar dispar*), experience reduced annual growth, canopy dieback, and death.

**Modeled hosts:** red oak and white oak species

**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
**Oak Wilt** *Ceratocystis fagacearum*

**Modeled hosts:** live oak and red oak species

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.

**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
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)
Bottom 49%
50–74%
75–95%
Top 5%–highest estimated BA losses

**Root diseases — all**

**Modeled hosts:** spruce and fir species, Douglas-fir, mountain hemlock, Port-Orford-cedar, paper birch, western red cedar, and the following pines: eastern white, jack, Jeffrey, longleaf, ponderosa, red, shortleaf, slash, and loblolly.

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.
**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 ridgelines and other sites with very dry, sandy soils.
**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 wasp can attack a wide variety of pine tree species, and stressed trees are those most often attacked.
SOUTHERN PINE BEETLE  *Dendroctonus frontalis*

**Modeled hosts:** eastern white, longleaf, shortleaf, slash, loblolly, pitch, pond, and Virginia pine

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

**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.

![Percentage of total basal area loss by watershed](image1)

![Watersheds ranked by basal area loss hazard](image2)
**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.

- **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%

- **50–74%**

- **75–95%**

- **Top 5%–highest estimated BA losses**
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.
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.

| Host extent (little to no BA loss) | 1–4% | 5–14% | 15–24% | 25% or greater of total BA loss |
|-----------------------------------|------|-------|--------|-----------------------------|
| Bottom 49%                        | 50–74%| 75–95%| Top 5%–highest estimated BA losses |

2013–2027 National Insect and Disease Forest Risk Assessment
The western balsam bark beetle is the most conspicuous of a complex of pests which are responsible for high rates of tree mortality in subalpine 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*

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

**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.

**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%
- 50–74%
- 75–95%
- Top 5%—highest estimated BA losses
White pine blister rust  *Cronartium ribicola*

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

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 1950s 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*

**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 1950s 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.
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 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.

Modeled host: Alaska yellow-cedar
Laurel wilt, continued

141 Albert Buell/Mayfield, USDA Forest Service, Bugwood.org Symptoms–Wilted redbay foliage
141 Ronald F. Billings, Texas Forest Service, Bugwood.org Symptoms–Redbay trees dying from laurel wilt disease, center tree responding with epicormic sprouting
141 Ronald F. Billings, Texas Forest Service, Bugwood.org Symptoms–Redbay trunk with bark removed exposing sapwood with typical black staining caused by laurel wilt disease
141 R. Scott Cameron, Advanced Forest Protection, Inc., Bugwood.org Symptoms–Redbay mortality on Jelly Island caused by laurel wilt disease

Maple decline

142 Jason Shanman, Vitaltreen, Bugwood.org Damage–Urban tree decline
143 Randy Cry, Greenbrier, Bugwood.org Symptoms–Planted maple maps are on the decline since they were planted in full sun
143 Jason Shanman, Vitaltreen, Bugwood.org Damage–Urban tree decline

Mountain pine beetle

144 Dave Powell, USDA Forest Service Damage–Old group of trees killed, Garber Creek area, South Platte Ranger District, Pike National Forest
145 Whitney Cranushaw, Colorado State University, Bugwood.org Infestation–Recently killed and fraying lodgepole pine. Rabbit Ear Peaks, Routt County, Colorado, September 3, 2007
146 Steven Katocha, USDA Forest Service, Bugwood.org Damage–Pitch tubes. Medicine Bow Mountains, southeast Wyoming
147 Ronald F. Billings, Texas Forest Service, Bugwood.org Infestation
148 Whitney Cranushaw, Colorado State University, Bugwood.org Damage–Adult excavating tunnel. Although this tree is still producing pitch, it has been heavily attacked by mountain pine beetle, and this adult beetle is excavating a larval gallery, treading the oozing pitch

Myzospira thrips

79 University of California Riverside Center for Invasive Species Research Nasa thrips, Klaubothrips myzospira

Oak decline and syrmea diaper diaper

146 USDA Forest Service–Forest Health Protection–St. Paul Archive, USDA Forest Service, Bugwood.org Symptoms–oak decline
147 Tim Tigges, Virginia Department of Forestry, Bugwood.org Damage–Late instar feeding on oak foliage
147 Tim Tigges, Virginia Department of Forestry, Bugwood.org Infestation–Chinony oak mortality and understory response ensuing defoliation
148 USDA APHIS PPQ Archive, USDA APHIS PPQ, Bugwood.org Adult–Aphids are normally wingless, and feed gregariously on spruce or Douglas-fir foliage
148 Joseph O'Brien, USDA Forest Service, Bugwood.org Infestation–Defoliation of oaks and other broadleaf trees
149 Joseph O'Brien, USDA Forest Service, Bugwood.org Moderate to severe decline symptoms in mature red oak
149 Tim Tigges, Virginia Department of Forestry, Bugwood.org Infestation–Heavy defoliation by larvae
150 William M. Greta, Forest Health Management International, Bugwood.org Adult(s)–Female adults and egg masses
149 Joseph O'Brien, USDA Forest Service, Bugwood.org Symptoms–oak decline
149 Jon Guichard, Bugwood.org Castanea, Syrmea diaper diaper

Oak wilt

150 William M. Greta, Forest Health Management International, Bugwood.org Infestation–Oak killed by oak wilt
151 Joseph O'Brien, USDA Forest Service, Bugwood.org Symptoms–Expanding oak wilt pocket
151 Paul A. Mistretta, USDA Forest Service, Bugwood.org Oak wilt, Texas red oak leaf symptoms
151 Joseph O'Brien, USDA Forest Service, Bugwood.org Oak wilt mortality caused by oak wilt
151 Paul A. Mistretta, USDA Forest Service, Bugwood.org Oak wilt, Live oak leaf symptoms

Ohio rust

78 Paul Cannon, USDA Forest Service Ohio rust, Purpurea pupa

Root diseases–all

152 Joseph O'Brien, USDA Forest Service, Bugwood.org Symptoms–Windthorst caused by Armillaria root rot in a large bur oak on a golf course
153 Robert L. James, USDA Forest Service, Bugwood.org Symptoms–Changes in tree density and clusters of young trees or brush associated with tree mortality are good indicators of root disease
153 Andrey Kuzma, National Forest Centre–Slovakia, Bugwood.org Symptoms–Root rot
153 USDA Forest Service Archive, USDA Forest Service, Bugwood.org Laminated root disease infestation–yellow shrubs filling gaps caused by conifer mortality

Photor Credits

145 Whitney Cranushaw, Colorado State University, Bugwood.org Damage–Pitch tubes. Medicine Bow Mountains, southeast Wyoming
141 Ronald F. Billings, Texas Forest Service, Bugwood.org Pitch tubes caused by roundheaded pine beetle attacks on ponderosa pine
157 USDA Forest Service, Southwestern Region Ponderosa pine mortality caused by roundheaded pine beetle in the Pinaleo Mountains, Arizona
157 USDA Forest Service, Southwestern Region Aerial view of ponderosa pine mortality caused by roundheaded pine beetle in the Pinaleo Mountains, Arizona
157 USDA Forest Service–Ogden Archive, USDA Forest Service, Bugwood.org Galleries
158 William M. Greta, Forest Health Management International, Bugwood.org Adult(s)–Female
159 William M. Greta, Forest Health Management International, Bugwood.org Damage–Aerial view of tree mortality in pine plantations
160 Ronald F. Billings, Texas Forest Service, Bugwood.org Infestation–Infection–Aerial view of spot
160 USDA Forest Service, Region 6, Southern Archive, USDA Forest Service, Bugwood.org Adult
161 Ronald F. Billings, Texas Forest Service, Bugwood.org Damage–Loss of killed pine trees by southern pine beetles
161 Erin G. Valley, USDA Forest Service–SRS 4512, Bugwood.org Damage
161 Ronald F. Billings, Texas Forest Service, Bugwood.org Infestation–Little Lake Creek Wilderness October 7, 1992
162 Elizabeth White, USDA Forest Service, Bugwood.org Adult–Aphids are normally wingless, and feed gregariously on spruce or Douglas-fir foliage
163 Jeff Whiles, USDA Forest Service, Bugwood.org Adult–Aphids are normally wingless, and feed gregariously on spruce or Douglas-fir foliage
163 Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org Damage
163 Petr Kopalova, State Phytosanitary Administration, Bugwood.org Damage
163 Petr Kopalova, State Phytosanitary Administration, Bugwood.org Damage
164 William M. Greta, Forest Health Management International, Bugwood.org Adult
165 William M. Greta, Forest Health Management International, Bugwood.org Damage–Spruce beetle mortality
165 USDA Forest Service–Ogden Archive, USDA Forest Service, Bugwood.org Galleries
165 Whitney Cranushaw, Colorado State University, Bugwood.org Damage–Tree mortality along White River in Rio Blanco County
166 Andis Rights, USDA Forest Service, Bugwood.org Damage–Infected Sitka spruce, early 1980s
167 Edward H. Hulsink, USDA Forest Service, Bugwood.org Adult(s)–and eggs
167 Whitney Cranushaw, Colorado State University, Bugwood.org Damage–Tree mortality along White River in Rio Blanco County
168 Paul E. Hennes, USDA Forest Service, Bugwood.org Fruiting bodies–dead Sitka spruce & hemlock in southeast Alaska
170 Joseph O'Brien, USDA Forest Service, Bugwood.org Symptoms–Coast live oak dying from P. ramorum infection
### Photo Credits

| PAGE | PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|------|--------------|-------------------------------|
| 171  | Joseph O’Brien, USDA Forest Service, Bugwood.org | Symptoms—Sudden oak death (omourum canker) symptoms on coast live oak. |
| 171  | Bruce Moltzan, USDA Forest Service, Bugwood.org | Symptoms. |
| 171  | Joseph O’Brien, USDA Forest Service, Bugwood.org | Symptoms—Tip drop symptoms of sudden oak death on tanoak. |
| 171  | Joseph O’Brien, USDA Forest Service, Bugwood.org | Sign—P.tannum line on coast live oak. |

### Western balsam bark beetle

| PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|--------------|-------------------------------|
| 172 | Javier Mercado, Colorado-state University, Bugwood.org | Adult. |
| 173 | Elizabeth Weintraub, USDA Forest Service, Bugwood.org | Damage. |
| 173 | Scott Turnock, USDA Forest Service, Bugwood.org | Galleries. The distinctive gallery pattern results from the male excavating a central nidus chamber from which the female radially radiates out to produce their egg galleries. |
| 173 | Ladd Livingston, Idaho Department of Lands, Bugwood.org | Damage—Trees killed typically have bright red crowns for a year or two after death. |
| 173 | USDA Forest Service—Ogden Archive, USDA Forest Service, Bugwood.org | Infestation. |

### Western pine beetle

| PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|--------------|-------------------------------|
| 174 | Emric G. Valley, USDA Forest Service—SRS-4552, Bugwood.org | Adult. |
| 175 | James Esswit, Bugwood.org | Damage—A still photograph of site in the Dixie Mountains of west Texas confirms a stand of dead ponderosa pines killed by western pine beetles. |
| 175 | Kenneth E. Gibson, USDA Forest Service, Bugwood.org | Damage—Pitch tubes. |
| 175 | Kenneth E. Gibson, USDA Forest Service, Bugwood.org | Damage—Bark sloughing off of trees. |
| 175 | William M. Ciesla, Forest Health Management International, Bugwood.org | Damage—Galleries. |

### Western spruce budworm

| PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|--------------|-------------------------------|
| 176 | William M. Ciesla, Forest Health Management International, Bugwood.org | Infestation—Aerial view of defoliation. |
| 177 | USDA Forest Service, Region 4, Intermountain Archive, USDA Forest Service, Bugwood.org | Adult moth. |
| 177 | Dave Powell, USDA Forest Service, Bugwood.org | Damage—Areal Balsam Mountains, Bear Creek Ranger District, Malheur National Forest, southeastern Oregon. |
| 177 | William W. Ciesla, Forest Health Management International, Bugwood.org | Larvae(s). |
| 177 | David J. Moreno, University of Georgia, Bugwood.org | Damage. |

### White pine blister rust

| PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|--------------|-------------------------------|
| 178 | Chris Schreep, University of Idaho, Bugwood.org | Sign—Blister rust sporeulating. |
| 179 | Mitra mojoza Department of Natural Resources (MDNR) Archive, MDNR, Bugwood.org | Symptoms. |
| 179 | USDA Forest Service—Ogden Archive, USDA Forest Service, Bugwood.org | Symptoms. |
| 179 | John W. Schwant, USDA Forest Service, Bugwood.org | Sign—Rust sporeulating on the bole of an infected tree. |
| 179 | Ralph Williams, USDA Forest Service, Bugwood.org | Infested stand. |
| 180 | Susan K. Hagie, USDA Forest Service, Bugwood.org | Symptoms—Stem canker eventually girdle and kill trees. |
| 181 | USDA Forest Service—Ogden Archive, USDA Forest Service, Bugwood.org | Sign—Urediospores on R1 spp. |
| 181 | Joseph O’Brien, USDA Forest Service, Bugwood.org | Symptoms. |
| 181 | H.J. Larsen, Bugwood.org | Sign—Close-up view of the area of white pine blister rust (Cronartium ribicola) on the branch of a pine tree. |
| 181 | Joseph O’Brien, USDA Forest Service, Bugwood.org | Symptoms—Small “flagged branches”. |

### Winter moth

| PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|--------------|-------------------------------|
| 182 | Dimitrios Avtar, NAGREF-Forest Research Institute, Bugwood.org | Larvae. |
| 183 | Dimitrios Avtar, NAGREF-Forest Research Institute, Bugwood.org | Larvae(s). |
| 183 | Milan Zubrik, Forest Research Institute, Slovakia, Bugwood.org | Adult. |
| 183 | Dimitrios Avtar, NAGREF-Forest Research Institute, Bugwood.org | Damage. |
| 183 | Milan Zubrik, Forest Research Institute, Slovakia, Bugwood.org | Larvae. |

### Yellow-cedar decline

| PHOTO CREDIT | DESCRIPTOR AND/OR DESCRIPTION |
|--------------|-------------------------------|
| 184 | Paul E. Hennon, USDA Forest Service, Bugwood.org | Symptoms in southeast Alaska. |
| 185 | Paul E. Hennon, USDA Forest Service, Bugwood.org | Symptoms in Alaska. |
| 185 | Paul E. Hennon, USDA Forest Service, Bugwood.org | Symptoms in southeast Alaska. |

### Acronyms

- **APHIS PPQ**: Animal and Plant Health Inspection Service, Plant Protection and Quarantine
- **BA**: Boreal 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
- **FHPT**: 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-NCDC**: National Oceanic and Atmospheric Association National Climate Data Center
- **NCRS**: Natural Resources Conservation Service
- **PET**: Potential Evapotranspiration
- **PI**: Productivity Index
- **PRISM**: Parameter-estimation Regression 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
- **SDE**: Spatial Data Library (Maintained by FHTET)
- **STATSGO**: 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