Interactions among insects and weeds in western U.S. forests

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Bark beetles

• 550 species in North America.

• Relatively few are economically important.

• Regulate certain aspects of primary production, nutrient cycling, ecological succession, and the size, distribution and abundance of forest trees.

Robber fly (Asilidae) predating on red turpentine beetle (*Dendroctonus valens*) attracted to residual trees following harvesting, Eldorado National Forest, California.
<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Primary host(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona fivespined ips</td>
<td>Ips lecontei</td>
<td>Pinus ponderosa</td>
</tr>
<tr>
<td>California fivespined ips</td>
<td><em>I. paraconfusus</em></td>
<td><em>P. contorta, P. jeffreyi, P. lambertiana, P. ponderosa</em></td>
</tr>
<tr>
<td>Douglas-fir beetle</td>
<td><em>Dendroctonus pseudotsugae</em></td>
<td><em>Pseudotsuga menziesii</em></td>
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<tr>
<td>eastern larch beetle</td>
<td><em>D. simplex</em></td>
<td>Larix laricina</td>
</tr>
<tr>
<td>fir engraver</td>
<td><em>Scolytus ventralis</em></td>
<td>Abies concolor, A. grandis, A. magnifica</td>
</tr>
<tr>
<td>Jeffrey pine beetle</td>
<td><em>D. jeffreyi</em></td>
<td>P. jeffreyi</td>
</tr>
<tr>
<td>mountain pine beetle</td>
<td><em>D. ponderosae</em></td>
<td><em>P. albicaulis, P. contorta, P. flexilis, P. lambertiana, P. monticola, P. ponderosa</em></td>
</tr>
<tr>
<td>northern spruce engraver</td>
<td><em>I. perturbatus</em></td>
<td><em>Picea glauca, Pi. x lutzii</em></td>
</tr>
<tr>
<td>pine engraver</td>
<td><em>I. pini</em></td>
<td><em>P. contorta, P. jeffreyi, P. lambertiana</em></td>
</tr>
<tr>
<td>piñon ips</td>
<td><em>I. confusus</em></td>
<td><em>P. edulis, P. monophylla</em></td>
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<tr>
<td>roundheaded pine beetle</td>
<td><em>D. adjunctus</em></td>
<td><em>P. arizonica, P. engelmannii, P. flexilis, P. leiophylla, P. ponderosa, P. strobiformis</em></td>
</tr>
<tr>
<td>southern pine beetle</td>
<td><em>D. frontalis</em></td>
<td><em>P. engelmannii, P. leiophylla, P. ponderosa</em></td>
</tr>
<tr>
<td>spruce beetle</td>
<td><em>D. rufipennis</em></td>
<td><em>Pi. engelmannii, Pi. glauca, Pi. pungens, Pi. sitchensis</em></td>
</tr>
<tr>
<td>western balsam bark beetle</td>
<td><em>Dryocoetes confusus</em></td>
<td><em>A. lasiocarpa</em></td>
</tr>
<tr>
<td>western pine beetle</td>
<td><em>D. brevicomis</em></td>
<td><em>P. coulteri, P. ponderosa</em></td>
</tr>
</tbody>
</table>

Fettig and Hilszczanński 2015 in Bark Beetles: Biology and Ecology of Native and Invasive Species
Area impacted by year, western U.S., 2000–2016

Fettig et al. (2020) in Disturbance and Sustainability in the Forests of the Western United States

~2.8 million hectares burned annually nationwide
• Pioneers use a combination of random landings and visual orientations followed by olfactory and gustatory cues.

• Most tree-killing species have highly-evolved chemical communication systems (e.g., in the western pine beetle, females release exo-brevicomin, which in combination with the host monoterpene myrcene is attractive to conspecifics. Frontalin, produced by males, enhances attraction).
Bluestain fungi (*Ophiostoma* sp.) in the sapwood of ponderosa pine killed by western pine beetle, Sierra National Forest, California.
The extent of tree mortality resulting from bark beetles may be limited to small spatial scales (e.g., individual trees or small groups of trees at endemic or transient population levels) or may affect entire landscapes during outbreaks (i.e., tens of millions of hectares in western North America).
Bark beetles are sensitive to thermal conditions conducive to population survival and growth. Shifts in temperature and precipitation affect:

- Fecundity and fitness
- Phenology and voltanism
- Predators, parasites, competitors and symbionts
- Host finding and colonization success
- Host physiology
Intensification of outbreaks and impacts

Mountain pine beetle (*D. ponderosae*)
(inciting factor – increase in winter temps)

Spruce beetle (*D. rufipennis*)
(inciting factor – increase in summer temps)

Western pine beetle (*D. brevicomis*)
(inciting factor – temps X drought)

Pinyon ips (*I. confusus*)
(inciting factor – temps X drought)
In a period of two years, 70% of trees and 93% of basal area were killed. All ponderosa pine were colonized by western pine beetle (Fettig et al. 2019).
Impacts of mountain pine beetle outbreaks

• A network of 125 0.081-ha circular plots in Colorado, Idaho, Montana, Utah and Wyoming.

• Overall, significant reductions in mean dbh (by 5.3%), mean QMD (by 8.6%), mean tree height (by 15.9%), mean number of trees (by 40.8%), mean basal area (by 52.9%), and mean stand density index (SDI) (by 51.8%) were observed.
Significant reductions in tree density were observed in all diameter classes, except the smallest (midpoint = 10 cm, 5-cm classes). Most mortality attributed to mountain pine beetle, especially in the larger-diameter classes.
Changes in understory vegetation

- Total understory cover and cover of shrubs and graminoids remained unchanged, while cover of forbs and invasive weeds increased.

- By 2018, 20% of plots contained invasive weeds. Invasive weed abundance increased by ~31% (from 7,482 to 9,825 individual plants).
Six invasive weeds were documented:

- Canada thistle \( \text{Cirsium arvense} \) (L.) Scop.
- Bull thistle \( \text{C. vulgare} \) (Savi) Ten.
- Musk thistle \( \text{Carduus nutans} \) L.
- Lamb’s quarters \( \text{Chenopodium album} \) L.
- Prickly lettuce \( \text{Lactuca serriola} \) L.
- Sulphur cinquefoil \( \text{Potentilla recta} \) L.

Canada thistle was dominant representing \(~95\%\) of total weed abundance, and most widely distributed occurring on \(20\%\) of plots.

Bull thistle was the next most common invasive weed, and was present on \(4\%\) of plots. The remaining four weed species each occurred on \(1–2\%\) of plots.
Weed abundance was most positively correlated with canopy cover, cover of shrubs, litter, bare ground, and percent dead trees in 2014.

By 2018, abundance of weeds was only positively correlated with snag fall. The mean percentage of fallen trees in plots with weeds was greater than twice that in plots without weeds.

A key factor promoting weed invasion is propagule pressure. Many plots within our network that contained invasive weeds had nearby (within ~250 m) weed populations, usually along roadways.
The soil disturbance created when snags tip up and fall appears prone to establishment and spread of invasive weeds. Canada thistle (here in a plot in Colorado) frequently invaded these sites and spread to nearby less-disturbed areas.
Only 24.7% of snags have fallen. The predicted half-life is ~16 YSD after which the function predicts a fairly linear, ~0.04/year decline in snag survival probability 15–30 YSD.
Global literature review

- Only two studies addressed the influence of bark beetle outbreaks on invasive weeds.
  - McCambridge et al. (1982) noted a large increase in musk thistle about 5 years after a mountain pine beetle outbreak in ponderosa pine in Colorado.
  - Crotteau et al. (2020) reported no changes in invasive weeds for ~11 years following a mountain pine beetle outbreak in Montana.

Our global search only yielded 23 papers. All studies were from North America (16) and Europe.
Some related ongoing research in California

- Overall, 49% of trees died. Ponderosa pine exhibited the highest levels of mortality (90%).

- About 22% of plots had invasive weeds:
  - Cheatgrass (*Bromus tectorum* L.)
  - ripgut brome (*Bromus diandrus* Roth)
  - bull thistle
  - yellow star-thistle (*Centaura solstitialis* L.)
  - mullein (*Verbascum thapsus* L.)
  - Himalayan blackberry (*Rubus armeniacus* Focke)
Thank You!

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