Ecological Risk Assessments for Insect Species Emerged from Western Larch Imported to Northern Minnesota

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Abstract

Forest products imported intra-continentally are potential pathways for introducing native insect species into areas where they were not previously found. While the risk associated with importation of exotic insects into foreign lands is well documented, native species pose similar threats. Ecological risk assessments were conducted on seven species of native insects (*Tetropium velutinum* LeConte, and *Pygoleptura nigrella* [Say] [Coleoptera: Cerambycidae], *Phaenops drummondi* [Kirby] [Coleoptera: Buprestidae], *Stephanopachys substriatus* [Paykull] [Coleoptera: Bostrichidae], *Dendroctonus pseudotsugae* Hopkins and *Scolytus laricis* Blackman [Coleoptera: Scolytidae], and *Camponotus noveboracensis* [Fitch] [Hymenoptera: Formicidae]) that emerged from western larch logs imported into northern Minnesota. The ecological risk of each species was assessed considering the following factors: economic impact, host specificity, potential for associated organisms, survey potential, pathway potential, establishment potential, and mitigation potential. Following suggestions provided in this document will minimize the likelihood that more western forest insect species will be introduced into Minnesota and other areas of the US.

Keywords*:* Ecological risk assessment, forest insects, invasive insects, woodborers, false powderpost beetles, bark beetles, carpenter ants, Cerambycidae, Buprestidae, Bostrichidae, Scolytidae, Formicidae.

Project Background

Threats posed by exotic species on native ecosystems are well documented and wide ranging (Simberloff 1981; Liebhold et al. 1995; Williamson 1996; Krcmar-Nozic et al. 2000). However, significant risks also exist in moving native species intra-continentally and introducing these species into areas where they were not found previously. It is essential that natural resource managers, corporate and private businesses, and government agencies begin to consider the possible ecological and economic threats posed by indigenous exotic insects.

In May 2001, the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, was found in traps baited with pheromones targeting the eastern larch beetle, *Dendroctonus simplex* (LeConte). Both of these bark beetle species are members of a genus known for its ability to kill trees (Wood 1982). Three beetles (2 females, 1 male) were captured in flight traps 7 miles north of Cohasset, Minnesota (Itasca County), and the *D. pseudotsugae* identification was verified by Dr. Donald E. Bright (Canadian National Collection, Ottawa, Canada). Concern about possible economic and ecological impacts from *D. pseudotsugae* on native Minnesota forests, specifically those in the Laurentian Mixed Forest Province (Minnesota Department of Natural Resources, 2003), was the impetus for a University of Minnesota funded Rapid Agricultural Response Project entitled: Introduction of an Exotic Forest Pest into Northern Minnesota: Monitoring and Damage Assessment. The objectives of this project were to (1) determine the extent of establishment of *D. pseudotsugae* and associated western forest insects in northern Minnesota and (2) educate and develop guidelines for the Minnesota wood products industry related to the importation of barked logs from other regions of North America.

During the course of the assessment of Itasca County, Minnesota, for *D. pseudotsugae*, it became evident that large quantities of large diameter barked logs of western larch, *Larix occidentalis*, were being imported into this region by a commercial entity. *Larix occidentalis* is a recorded host for *D. pseudotsugae* (Wood 1982), and examination of the barked logs in a log deck near Cohasset revealed the very distinctive galleries of *D. pseudotsugae* and yielded live adult beetles on several occasions.

Results from objective 1 of the assessment indicated that other species of western forest insects were also emerging from *L. occidentalis*, logs imported into Minnesota. In 2002, in addition to *D. pseudotsugae*, several woodborers, three bark beetle species and various other insects were reared out of logs (Tables 1 and 2). Two species of pathogenic fungi not known to occur in Minnesota were also isolated from the wood importation site. Funnel traps placed around Grand Rapids, Minnesota, captured 29 *D. pseudotsugae*. Based on consecutive years of trap catches and distances of beetle captures from the suspected introduction point, it was speculated that a *D. pseudotsugae* population was likely to have been established in northern Minnesota.

Because forest insect species native to the western US were reared from western larch imported into Minnesota, it was imperative that an ecological risk assessment be undertaken to determine possible ecological and economic impacts that these species could have on the forest resources of Minnesota. While the scope of reference for this document is primarily the Laurentian Mixed Forest Province of Minnesota (Minnesota Department of Natural Resources, 2003), it could be used as a guideline for similar forest types in eastern North America.

Ecological Risk Assessment for Western Forest Insects Found in Minnesota

Host trees/potential hosts

The ecological range and geographic distribution of a tree species are dictated by various factors, including climate, microclimate, elevation, and aspect. North America has several conifer forest types that have distinct ecological boundaries. Several conifer species will be considered as hosts and/or potential hosts for seven species of forest insects imported from western conifer forests into the Laurentian Mixed Forest Province of northern Minnesota in this ecological risk assessment. Important tree species considered in this assessment include two western species, *Larix occidentalis* and *Pseudotsuga menziesii*, and tree species native to Minnesota including *Larix laricina*, *Picea mariana*, *Picea glauca*, *Abies balsamea*, and *Pinus resinosa* (Table 3). Because these insects were transported into Minnesota in *L. occidentalis*, it is likely that *L. laricina* and to a lesser extent the other Minnesota conifers could serve as a host species for these insects.

The distribution of *L. occidentalis* is relatively restricted compared with that of the other conifer species discussed, and the species is not indigenous to Minnesota (Figure 1). Its range is confined to northwestern Montana, north and central Idaho, and primarily eastern portions of Washington and Oregon. In contrast, *L. laricina* is widely distributed and is found throughout Minnesota and the Lake States Region (Figure 2). Its range extends from New England to Quebec and west to Alaska. *Pseudotsuga menziesii,* the primary host for *D. pseudotsugae*, has a larger geographic range than *L. occidentalis* (Figure 3), however, it does not occur naturally in Minnesota. *Pseudotsuga menziesii* has been planted in arboretums, landscape plantings, Christmas tree plantations, and experimental plantings in some parts of Minnesota. While *Pseudotsuga menziesii* and *L. occidentalis* are sympatric species, the distribution of tamarack does not overlap with either species (Figure 4). Because the ranges of western tree species do not overlap with *L. laricina*, there is a concern that insects and associated organisms from trees from one forest type may adversely affect trees in forests of another region.

Target insects

A total of 16 preliminary identified species of insects were reared out of western larch imported into Minnesota with other species yet to be identified (Tables 1 and 2). From this list, seven species of insects were selected and ecological risk assessments were conducted. These species are western larch borer, *Tetropium velutinum* LeConte (Cerambycidae), *Pygoleptura nigrella* (Say) (Cerambycidae), a flathead woodborer, *Phaenops drummondi* (Kirby) (Buprestidae), a false powderpost beetle, *Stephanopachys substriatus* (Paykull) (Bostrichidae), Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins (Scolytidae), larch engraver, *Scolytus laricis* Blackman (Scolytidae), and a carpenter ant, *Camponotus noveboracensis* (Fitch) (Formicidae). For each species, information is provided on known distribution, biology, and estimated risk to MN forest resources.

Some of the insects that emerged from the western larch logs in this study may have been opportunistic local species that utilized overwintering sites under the bark, in bark or wood crevices, or within hollowed out section of the logs. The logs were collected in April and May of 2001 from a log deck located next to grassy wetlands and tamarack bogs. These logs may have been at the log deck area in Cohasset since the preceding fall when local insects might have colonized the logs. For example, the ground beetles, *Stenolophus comma* and *S. conjunctus* (Tables 1 and 2) are seed eaters associated with wet, grassy areas and could likely overwinter under bark of down trees (K. Will, UC-Berkeley, personal communication). Also, *Agonum gratiosum* is another wet area carabid beetle that climbs under bark to overwinter (K. Will, UC-Berkeley, personal communication). Thus, although these three species occur in the western US and in Minnesota, they are likely to have been local insects that found these logs as overwintering sites. Similarly, the carpenter ant, *C. noveboracensis* may also have been of local origin and may have set up satellite colonies in these logs.

Ecological risk assessment process

Ecological risk is based on a review of available literature for each insect, host tree species, and expert opinion accounting for possible hosts, insect biology, and modes of transport into Minnesota. These insects have been identified from logs already imported into Minnesota. This document will serve as a starting point in focusing attention on the intra-continental transport of timber products. In the future this document and approach could be expanded to include other insects that pose a risk to Minnesota forests, but have not yet been found (e.g., southern pine beetle, mountain pine beetle, Douglas-fir tussock moth) in the state.

The overall risk rating is based on an assessment of the potential for a given western species to become established, to survive and reproduce in native tree species, to impact local ecological relationships, and to cause economic damage. The risk rating for each species is further subdivided to account for economic impact, host specificity, potential for associated organisms, survey potential, pathway potential, establishment potential, and mitigation potential. All subcategories of the ecological risk assessment are based on expert opinion and known biology of each species. Descriptions of rankings for each category are detailed in Appendix 1.

Project goals and management objectives

This document contains ecological risk assessments for seven species of insects reared from western larch imported into Minnesota. Our primary objective is to develop guidelines to protect Minnesota forest resources by assessing the ecological risk that accompanies each indigenous exotic insect species. Approaches to mitigation are included for each insect species.

Woodboring Insects

Three families of woodboring insects, Cerambycidae, Buprestidae, and Bostrichidae were reared from *L. occidentalis* imported into northern Minnesota. Typically, woodborers do not threaten healthy trees and are normally associated with natural or anthropogenic disturbances. However, some woodborers transmit plant pathogens, including pine wilt disease (Linit et al. 1983; Kobayashi et al. 1984; Luzzi et al. 1984) that can cause widespread tree mortality. Some woodborers pose an economic threat to log decks where they often degrade stored timber products with sapwood gallery excavations (Post and Werner 1988). While woodborers usually pose little ecological or economic threat within their native range, unknown consequences could result when native woodborers are transported intra-continentally to new ecosystems where they encounter new host species and the absence of mechanisms that regulate their populations.

As an example of the potential impacts that exotic woodborer species may have on native ecosystems, it is important to look at two recent introductions that are the focus of intense survey, manage, and eradication efforts in the United States and Canada. The Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Cerambycidae), has been introduced into parts of New York and Chicago from China (Haack et al. 1997; Poland et al. 1998). This species causes tree mortality in apparently healthy hardwood species, including *Acer* spp., *Salix* spp., *Ulmus americana*, *Betula* spp., and *Populus* spp. (USDA Forest Service 2002). If established, Asian longhorned beetle will cause significant losses in timber, recreational, and ecological resources, as well as shifting successional dynamics in eastern deciduous and northern hardwood forests towards more resistant tree species. The emerald ash borer, *Agrilus planipennis* Fairmaire (Buprestidae), from Asia has been detected in Michigan, has caused primary tree mortality to several species of ash, and could cause problems similar to the Asian longhorned beetle.

The Asian longhorned beetle and emerald ash borer are non-native invasive species. It is possible, however, that native woodboring beetles along with associated organisms transported into new forest types could cause similar changes in the Laurentian Mixed Forest Province of Minnesota. The following wood-boring species were reared from *Larix occidentalis* imported into Minnesota.

Cerambycidae

Tetropium velutinum LeConte

Tetropium velutinum, western larch borer, is a common woodborer that is found from British Columbia to central California, Montana and Utah (Kimmey and Furniss 1943; Wright and Harvey 1967; Furniss and Carolin 1977) (Figure 5). It is also been recorded in the Great Lakes area (Yanega 1996). Hosts include *Larix* spp., *Tsuga* spp., *Pseudotsuga menziesii*, *Abies* spp., *Picea* spp., and *Pinus* spp. (Webb 1911; Craighead 1923; Kimmey and Furniss 1943; Linsley 1962; Wright and Harvey 1967; Ross 1967; Furniss and Carolin 1977).

Although *T. velutinum* has been reported to attack and kill apparently healthy trees (Webb 1911; Craighead 1923), this beetle is usually associated with trees weakened by natural or anthropogenic disturbances. Fire, drought, insect defoliation, and bark beetles can all predispose trees to *T. velutinum* attack (Kimmey and Funiss 1943; Wright and Harvey 1967; Furniss and Carolin 1977).

From a survey of specimens housed at the University of Minnesota Insect Collection in St. Paul (UMNIC), *T. velutinum* has been collected in at least six Minnesota counties, primarily in the northern portion of the state. In the Upper Midwest it is likely to develop in *L. laricina* and *Abies balsamea* (Linsley and Chemsak 1997). Other species that it might infest in this region include *Picea mariana*, *P. glauca*, *Pinus resinosa*, *P. sylvestris*, *P. banksiana*, and *P. strobus* (Table 3). Because of the propensity of *T. velutinum* to attack weakened trees and its prior existence in Minnesota, this species is likely not a significant risk. However, where trees are stressed from disease or other factors, *T. velutinum* could cause tree mortality. Another important consideration is the consequences of genetic intermixing of two allopatric populations. Genetic intermixing of western and Minnesota populations of *T. velutinum* could shift behaviors or host range of offspring. Also, western populations may carry different fungi and microorganisms than their eastern counterparts and these may also be imported along with western *T. velutinum* populations.

In interior British Columbia, oviposition by *T. velutinum* occurred from May to August with eggs laid under loose bark or between bark scales shortly after parent emergence (Ross 1967). Larvae hatch from eggs and begin feeding in the phloem/cambium layer of host trees. Depending on the host tree, larvae enter the sapwood where pupation occurs (Webb 1911; Ross 1967). There is usually one generation per year of *T. velutinum*.

To reduce the impact of *T. velutinum* on forest products it is recommended that prompt salvage logging be conducted after forest disturbances that cause mortality and reduce tree vigor. Because *T. velutinum* larvae leave the phloem and tunnel into the sapwood, injured or dead trees should be removed as soon as possible.

<u>Overall Risk Rating: **Moderate**</u>

Because this species is endemic to northern Minnesota and is typically a secondary species, *T. velutinum* is deemed a moderate risk. However, there is a significant risk associated with introducing a western population of *T. velutinum* into Minnesota and subsequent interbreeding with native populations. Associated fungi and phoretic organisms (Kinn and Linit 1989; Lindquist and Wu 1991) that may not normally occur in Minnesota may also be imported along with western *T. velutinum* populations.

<u>Economic Impact: **Low**</u>

It is unlikely that *T. velutinum* will cause any economic damage to Minnesota forests. Unless intermixing of western and native populations shift the behavior or if western populations introduce a more pathogenic fungus, *T. velutinum* will rarely damage living trees. *Tetropium velutinum* does colonize weakened and dead trees, so if damaged trees are left on site for more than a year prior to salvage logging, the timber may be reduced in value.

Host Specificity: **Low**

Tetropium velutinum has been recorded from all conifer genera that occur in Minnesota. Colonization by *T. velutinum* would be restricted to conifer species.

Potential for Associated Organisms: **Moderate**

While it is unknown what associated organisms *T. velutinum* carries, other *Tetropium* spp. have been reported to carry several species of ophiostomatoid fungi (Jacobs et al. 2003). If western *T. velutinum* populations carry specific ophiostomatoid fungi, while Minnesota populations carry another, it is possible that new fungi could be introduced into Minnesota populations by conspecifics inhabiting the same host trees. Fungi introduced from a western *T. velutinum* population may have different levels of pathogenicity in native Minnesota trees.

Survey Potential: **Low**

Cerambycids, including *T. velutinum*, are cryptic species with much of their lives spent under the bark or within the sapwood of host trees. These life history traits inhibit the surveying for *T. velutinum* on logs being transported into Minnesota. To be the most effective, logs should be debarked, with the bark and sapwood thoroughly investigated for either presence of larvae or sapwood entrance holes. Sapwood entrance holes are elliptical in shape and range from 5.0 x 2.7 to 6.0 x 3.5 mm. If this sampling is done within Minnesota, bark and any remnants from the sampling should either be chipped and/or burned. It is likely larvae are still present in the sapwood gallery if entrance holes are located and no exit holes exist. Wood should be processed immediately in such cases.

<u>Pathway Potential: **High**</u>

Overall, entrance pathways of western populations of *T. velutinum* are limited in scope but the potential of introductions from these sources is high. Two pathways of immediate concern in northern Minnesota are whole logs imported for log home building and logs used for extraction of a natural polysaccharide. Larch arabinogalactan is a polysaccharide extracted from *Larix* spp. that is used in health supplements, consumer products, and industrial markets (Larex website: www.larex.com). Other possible pathways include individuals moving firewood or logs for personal use (e.g., rustic construction, furniture, etc.).

<u>Establishment Potential: **High**</u>

Because there are native populations of *T. velutinum* present in Minnesota, it is likely that western populations would also become established in the area. It is also likely that western populations will interact with native populations in host trees. This increases the likelihood that associated fungi or other microorganisms may be transported from western *T. velutinum* to native Minnesota beetles.

<u>Mitigation Potential: **Moderate**</u>

Specific methods to reduce western introductions of this species or mitigate concerns include:

1. Reduction of whole log imports into Minnesota.
2. Thorough inspection of whole logs brought into Minnesota.

3. Using wood in a manner that corresponds with knowledge of life history characteristics of *T. velutinum*.
    a. Transport logs before *T. velutinum* flight period occurs in the spring.
    b. Use logs before adult emergence. Used before May 15 (Webb 1911)
4. Monitoring traps baited for woodboring insects (Phero Tech Inc., BC, Canada) around log yards.

Pygoleptura nigrella (Say)

Little is known about the biology of *Pygoleptura nigrella*, so it is difficult to estimate the risk of this species to Minnesota forests. Boreal North American forests from Alaska to Nova Scotia and south to Oregon provide habitat for *P. nigrella* (Linsley and Chemsak 1976). A survey of the UMNIC revealed that *P. nigrella* has been collected from at least seven Minnesota counties, with most of the localities in the northern half of the state. No host information was associated with any of the specimens in the collection. Two subspecies of *P. nigrella* have been identified and one of these subspecies, *P. nigrella nigrella* (Say) has been recorded in *Picea glauca*, *Pinus resinosa*, *Pseudotsuga menziesii*, *Abies* spp., and *Larix laricina* (Linsley and Chemsak 1976, 1997).

Overall Risk Rating: **Low**

As with most Cerambycidae, *Pygoleptura nigrella* is not an aggressive species and is likely associated with injured or dead tree material. Because of this, we do not deem this species a risk to MN forests.

Economic Impact: **Low**

It is unlikely that *P. nigrella* will cause any economic damage to Minnesota forests. Unless intermixing of western and native populations shifts the behavior or if western populations introduce an associated fungus, *P. nigrella* is unlikely to cause any damage to living trees. Consequently, the economic impact of *P. nigrella* is estimated to be low.

Host Specificity: **Low**

Pygoleptura nigrella likely has a wide host range and could likely colonize *Picea glauca*, *Picea mariana*, *Pinus* spp., *Abies balsamea*, and *Larix laricina* in Minnesota.

Potential for Associated Organisms: **Low**

Little research has been conducted on *P. nigrella* or its subspecies, so it is unknown what associated organisms it carries. Some cerambycids have associated nematodes (Linit et al. 1983; Kobayashi et al. 1984; Luzzi et al. 1984) or fungi, however, the impact of these organisms on native trees is unknown.

Survey Potential: **Low**

Pygoleptura nigrella likely inhabits the bark and sapwood of host trees, therefore, surveying for this species likely will be difficult. To adequately determine if a wood borer exists in a log, bark must be removed, checked for larvae, and then burned. In addition, sapwood entrance holes should be located.

Pathway Potential: **High**

Although little is known about the biology of *P. nigrella*, it was reared from western larch imported into Minnesota. Because of this, it can be assumed to be in whole log imports and thus has a high potential for repeated introductions. Logs imported for cabin building and larch arabinogalactan extraction purposes would be the major pathway.

Establishment Potential: **Moderate**

Because subspecies of *P. nigrella* has been recorded in species of *Picea*, *Pinus*, *Abies* and *Larix* it is likely to become established in Minnesota forests and may already be present. Beetles with a wide breadth, similar to *P. nigrella*, have a higher likelihood of becoming established as more host trees species are available. Based on host preferences of a subspecies, *Pinus resinosa*, *Picea mariana*, *P. glauca*, *Abies balsamea*, and *Larix laricina* could all provide possible host trees in Minnesota.

Mitigation Potential: **Moderate**

Specific recommendations for reducing the risk of *P. nigrella* to Minnesota forests include:

1. Closely monitoring all whole logs shipped into Minnesota.
2. Reduction of importation of whole logs into Minnesota from western states.
3. Prompt debarking of logs either at point of entry or on site.
4. Using wood in a manner that corresponds with knowledge of life history characteristics.
    a. Move wood when not infested by beetle
    b. Use before emergence of beetle.
5. Monitoring traps baited for woodboring insects (Phero Tech Inc, BC, Canada) around log yards.

Buprestidae

Phaenops drummondi (Kirby)

The flatheaded fir borer, *Phaenops drummondi,* is a common species found throughout much of the northern United States. It has been reported in western North America, Alaska, and in eastern forests (Burke 1919; Baker 1972; Furniss and Carolin 1977). It is recorded from Minnesota where it attacked *Larix laricina* (http://www.cedarcreek.umn.edu/insects/024046n.html) and has been collected primarily in the northwestern portion of the state, including at least three counties (UMNIC data). Host trees include *Larix occidentalis*, *Picea engelmanni*, *P. sitchensis*, *Tsuga heterophylla*, *T. mertensiana*, *Pseudotsuga menziesii*, and *Abies* spp. (Burke 1919).

Potential hosts in Minnesota for *P. drummondi* include *Larix laricina*, *Picea mariana*, *P. glauca*, *Abies balsamea*, and potentially *Pinus* spp. While *P. drummondi* typically attacks weakened trees, there is little economic impact associated with this species. Eggs are laid in bark crevices where larvae hatch and mine into the phloem. *Phaenops drummondi* larvae feed in the phloem and pupate in the bark and are not recorded to enter the sapwood. Populations of this species can build in areas where there has been large-scale natural disturbances or timber activities with slash left on site. Salvage logging and silvicultural treatments such as thinning can reduce the chances of attack by *P. drummondi*.

Phaenops drummondi flies throughout the summer months (Burke 1919; Dodds and Ross 2002) and has one generation per year. While it has been reported to attack and kill living trees on dry sites (Overhulser 2002), it is typically found in weakened or stressed trees (Scott 1974).

Overall Risk Rating: **Low**

Phaenops drummondi is native to northern Minnesota and is typically considered a secondary species. Thus, *P. drummondi* is deemed a low risk to forest resources in Minnesota. However, there is a significant risk associated with introducing a western population of *P. drummondi* into Minnesota and subsequent interbreeding with native populations. Not only could there be consequences from the interbreeding of non-native and native Minnesotan populations, but associated fungi and phoretic organisms may also be imported along with western *P. drummondi* populations.

Economic Impact: **Low**

Phaenops drummondi is unlikely to cause any economic damage to Minnesota forests. Unless intermixing of western and native populations shift the behavior or if western populations introduce problematic associated organisms *P. drummondi* will rarely cause economic concern. *Phaenops drummondi* occasionally colonizes trees on dry sites (Overhulser 2002), but the economic impact of this would be minimal.

Host Specificity: **Low**

With the exception of *Larix laricina*, no specific hosts for *P. drummondi* have been recorded in Minnesota. No host records were recorded along with insect specimens housed in the UMNIC. However, this beetle is found in species from the genera *Larix*, *Abies*, *Picea*, and *Pinus*. It is likely that *P. drummondi* colonizes species in these genera in Minnesota.

Potential for Associated Organisms: **Low**

Buprestid species can carry various fungi on their body and in their gut (Garcia and Morrell 1999). However, it is unknown what fungi, if any, *P. drummondi* carries.

Survey Potential: **Low**

Buprestids are cryptic insect species that develop under the bark of host trees. Thus, detection will be more difficult and take more diligence. If whole logs are brought into an area, bark should be removed and searched for the presence of larvae. If larvae are found, wood should be used promptly, debarked, and/or burned.

Pathway Potential: **High**

As long as barked whole logs are imported into Minnesota for commercial purposes, it is likely western populations of *P. drummondi* will continue to be introduced into this region. Logs imported for cabin home building or larch arabinogalactan will continue to be introduction pathways for *P. drummondi*.

Establishment Potential: **High**

Populations of *P. drummondi* already exist in Minnesota and it is likely that western populations would easily establish themselves in the area. Also, *P. drummondi* has a wide host breadth making encountering a suitable host tree likely.

Mitigation Potential: **Moderate**

Specific methods to reduce the risk of introducing western populations of *P. drummondi* into Minnesota include:

1. Reduction of whole logs into northern Minnesota.
2. Closely monitoring all whole logs shipped into Minnesota.
3. Prompt debarking of all logs and then burning remaining bark.
4. Importing logs so that harvest and use correspond to life history of *P. drummondi*.

5. Emergence traps placed to monitor if logs entering Minnesota contain *P. drummondi*. Data from these traps could provide life-history information that could refine the time frame for use of logs in Minnesota.

Bostrichidae

Bostrichids are commonly known as false powderpost beetles or branch and twig borers and typically colonize deciduous trees and shrubs, but are also found in conifers (Baker 1972; Furniss and Carolin 1977; Borror et al. 1992). Adult bostrichids can colonize freshly cut, partially seasoned, or seasoned wood, where larvae usually feed in the sapwood (Baker 1972; Furniss and Carolin 1977). Several members of the Bostrichidae are also stored grain pests (Fisher 1950).

Stephanopachys substriatus (Paykull)

Stephanopachys substriatus is native to northern Europe, Asia, and North America (Furniss and Carolin 1977). In North America, it occurs in most of the northern states and western provinces (Fisher 1950; Baker 1972; Furniss and Carolin 1977). It has been recorded to colonize *Pseudotsuga menziesii*, *Tsuga* spp., *Pinus* spp., and *Abies* spp. (Fisher 1950; Baker 1972; Furniss and Carolin 1977). Also, it has been reported to attack tan bark, furniture, and stored lumber (Fisher 1950). Specimens housed at the UMNIC revealed that *S. substriatus* has been recorded from seven counties distributed throughout Minnesota. One series of specimens collected from Hennepin County were from *Pinus monticola* timber imported from the western US.

Overall Risk Rating: **Low**

Because *S. substriatus* is native to northern North America and has previously been found in Minnesota, this species poses a low risk to local forest resources. However, there is a significant risk associated with introducing a western population of *S. substriatus* into Minnesota and subsequent interbreeding with native populations.

Economic Impact: **Low**

It is unlikely *S. substriatus* will cause serious economic impact in Minnesota. *Stephanopachys substriatus* is already present in Minnesota and likely colonizes already dead tree material or stored timber products.

Host Specificity: **Low**

Stephanopachys substriatus has been recorded from four genera of trees. In addition it was reared out of *Larix occidentalis*, a previously unrecorded host, imported from Montana (Gilmore et al. 2003). Therefore, *S. substriatus* is considered to have a wide host range and low host specificity. Possible host trees in Minnesota include *Larix laricina*, *Pinus resinosa*, *Abies balsamea*, *Picea mariana*, and *P. glauca*.

Potential for Associated Organisms: **Low**

Little is known about Bostrichidae and associated organisms, but it appears that they do not carry associated fungi. Because of this, it is unlikely that western *S. substriatus* will introduce new fungi into Minnesota forests.

Survey Potential: **Low**

Stephanopachys substriatus colonizes the sapwood of host trees and determining if adults or brood are present would be difficult. If *S. substriatus* colonized logs, small circular sapwood entrance holes would be present, and could provide some indication of the species presence in the wood. However, it would be difficult to determine if *S. substriatus* was present in the wood or had already completed development and the brood had emerged.

<u>Pathway Potential: **Moderate**</u>

As long as whole logs are imported into Minnesota for commercial purposes, it is likely that *S. substriatus* will continue to be introduced into this region. Debarking of logs will not mitigate the introduction potential of western populations of *S. substriatus* into Minnesota. Logs imported for cabin home building or larch arabinogalactan extraction are introduction pathways for *S. substriatus*.

<u>Establishment Potential: **High**</u>

Because *S. substriatus* is already found in Minnesota and has a wide host breadth it is likely western populations could become established in the state.

<u>Mitigation Potential: **Moderate**</u>

Specific steps can be taken to reduce the likelihood that *S. substriatus* will continue to be introduced into Minnesota. However, some of these options are in direct conflict with mitigation options suggested for other species. These options include:

1. Use trees that have been dead for less than 18 months.
2. Do not allow cut logs to be stored in western states for long periods (>18 months) before being shipped to Minnesota.
3. If found to be infested by *S. substriatus* upon arrival in Minnesota, trees should be promptly used and remnants burned.
4. Log piles should be covered with tarps to reduce colonization and kill preexisting brood within logs.

Scolytidae

Bark beetles are some of the most destructive insects found in North American forests. Members of the genus *Dendroctonus* cause serious economic damage where they occur and high populations can conflict with timber management. Most bark beetles infest the phloem-cambium interface of host trees, but ambrosia beetles enter and reproduce in the sapwood (Bright 1976; Furniss and Carolin 1977; Wood 1982). Bark beetles typically colonize trees that are suffering from some kind of stress. This stress can be caused by small-scale stand disturbances (i.e., harvesting activity) or large-scale regional factors such as climate or drought.

Even though bark beetles themselves are a significant risk to trees and forest resources, associated organisms pose an equal threat. Specifically, many bark beetles have associated fungi that are inoculated into trees upon attack by the beetles (Harrington 1993; Paine et al. 1997; Klepzig et al. 2001). These fungi have various levels of pathogenecity to host trees. One of the most notable examples of the relationship between a bark beetle and a destructive fungus is between *Scolytus multistriatus* or *Hylurgopinus rufipes* and the fungus *Ophiostoma ulmi* that causes Dutch elm disease (Strobel and Lanier 1981). Two species of bark beetles were reared from western larch logs imported into Minnesota.

Dendroctonus pseudotsugae Hopkins

The Douglas-fir beetle, *Dendroctonus pseudotsugae*, is found throughout the western US wherever its primary host, *Pseudotsuga menziesii*, is found (Figure 6). While *D. pseudotsugae* primarily attacks Douglas-fir, it can also successfully reproduce in downed *Larix occidentalis*. *Dendroctonus pseudotsugae* is typically found in stressed or damaged trees, but as populations build, beetles subsequently attack and kill living trees.

The flight period for *D. pseudotsugae* occurs in early spring and there is one generation per year. Colonization of host trees is mediated by a complex pheromone system that includes host volatiles, aggregation, and anti-aggregation pheromones. These pheromones are well understood and have been incorporated into pheromone-based management strategies (Ross and Daterman 1994; Dodds et al. 2000; Ross et al. 2001).

While *Pseudotsuga menziesii* is rarely grown in Minnesota, there is a concern that *D. pseudotusgae* could successfully colonize native conifers. Because *D. pseudotsugae* has the ability to colonize downed *Larix occidentalis*, *L. laricina* could be a host in Minnesota. *Dendroctonus pseudotsugae* has successfully reproduced in *L. laricina* logs in the lab (Furniss 1976). While *L. laricina* is an obvious potential host, *Picea* spp. and *Abies balsamea* could also be colonized in Minnesota. *Dendroctonus pseudotsugae* also carries several species of fungi (Lewinsohn et al. 1994, Solheim and Krokene 1998; Neal and Ross 1999) and introduction of these into Minnesota is a potential additional threat. There is also the concern that *D. pseudotsugae* and *D. simplex* could hybridize within host trees.

Several management options exist for *D. pseudotsugae* and if it becomes established in Minnesota there are pre-existing technologies for monitoring, trapping, and protecting forest stands (Ross and Daterman 1994; Ross et al. 2001).

<u>Overall Risk Rating: **High**</u>

Because *D. pseudotsugae* can kill living trees in its native range and has been reported to successfully reproduce in *Larix laricina*, it could cause serious damage to areas containing this species in the Laurentian Mixed Forest Province. If *D. pseudotsugae* is established in Minnesota and populations build, large-scale losses of *L. laricina* could be expected. Perhaps more importantly, fungi associated with *D. pseudotsugae* could be introduced into Minnesota, transferred horizontally to *D. simplex* cohabitating tamarack with *D. pseudotsugae*, and then moved more efficiently into tamarack. These western fungi may or may not be more pathogenic to Minnesota trees that have not coevolved host defenses for these particular fungal species.

<u>Economic Impact: **High**</u>

If *D. pseudotsugae* attacks and kills tamarack in Minnesota there will be considerable economic damage. Large-scale losses of *L. laricina* are already occurring as a result of recent *D. simplex* outbreaks in Minnesota (Seybold et al. 2002). *Larix laricina* is used for pulp by the paper manufacturing industry in Minnesota.

<u>Host Specificity: **High**</u>

Dendroctonus pseudotsugae is a relatively host specific bark beetle. In its native range, *D. pseudotsugae* successfully reproduces only in living or dead *P. menziesii* and dead *Larix occidentalis*. However, in a laboratory study Furniss (1976) demonstrated that *D. pseudotsugae* could successfully reproduce in *Larix laricina*, making this tree species a concern for local establishment of *D. pseudotsugae* populations.

<u>Potential for Associated Organisms: **High**</u>

As mentioned above, it is likely *D. pseudotsugae* would introduce new fungi into Minnesota forests. In addition, *D. pseudotsugae* also carries mites and likely microorganisms other than fungi.

Survey Potential: **Moderate**

Dendroctonus pseudotsugae develops under the bark and feeds in the phloem of host trees. However, the galleries are distinct and easily identifiable (Wood 1982). *Dendroctonus pseudotsugae* brood often moves into the outer bark of host trees to complete development. Careful inspection of bark material is essential for successful detection of *D. pseudotsugae*. Depending on what time of the year logs or trees are moved, adult beetles could also be present and identifiable.

Pathway Potential: **High**

As long as barked whole logs are imported into Minnesota for commercial purposes, it is likely *D. pseudotsugae* populations will continue to be introduced into this region. In February 2004, nearly one year after a compliance agreement was reached between Minnesota Department of Agriculture and the log importer, live *D. pseudotsugae* adults were found under the bark of imported western larch logs at the log deck in Cohasset by the authors. Logs imported for cabin home building or larch arabinogalactan will continue to be introduction pathways for *D. pseudotsugae*.

Establishment Potential: **Moderate**

Dendroctonus pseudotsugae has been shown to successfully reproduce in *Larix laricina* (Furniss 1976). While it has not been shown to respond to and successfully reproduce in *L. laricina* in the forest outside the laboratory, there is a strong possibility that *D. pseudotsugae* could attack this species in Minnesota.

Mitigation Potential: **High**

Specific steps can be taken to reduce the likelihood that *D. pseudotsugae* will be introduced further into Minnesota. These options include:

1. Harvest trees after August and ship them promptly to Minnesota
2. Use trees that have been dead for more than 18 months.
3. Do not allow cut logs to be stored in western states that have high *D. pseudotsugae* populations before being shipped to Minnesota.
4. If logs are infested with *D. pseudotsugae*, bark should be removed and burned prior to the spring.
5. Cover log piles with tarps.
6. Monitor log storage facilities with pheromone-baited traps.
7. If *D. pseudotsugae* populations are found, pheromone-baited traps and the anti-aggregation pheromone MCH can be used to suppress populations and protect forest stands from infestation.

Scolytus laricis Blackman

The larch engraver, *Scolytus laricis*, is found in British Columbia, Washington, Oregon, Idaho, and Montana (Furniss and Carolin 1977) (Figure 7). *Scolytus laricis* has not been previously reported to occur in Minnesota. This species has been intercepted at wood entry points in Great Britain from logs exported from Canada (Winter 1991), but no record of establishment could be found. *Scolytus laricis* occurs in *Larix occidentalis* and *Larix lyallii* (Alpine larch) (Furniss and Johnson 2002). Typically, *S. laricis* colonizes stressed pole-sized trees, suppressed limbs, and slash (Furniss and Carolin 1977). Little else is known about the biology of this species.

Overall Risk Rating: **Moderate**

While it is unlikely *Scolytus laricis* itself would cause severe ecological or economical impacts, there is a strong concern for associated organisms coming in with these beetles. Other *Scolytus* spp. are known to vector pathogenic fungi that have caused severe ecological impacts in North America and Europe (Webber, 1990; Basset et al., 1992). Because the fungal complex associated with *S. laricis* is unknown, impact or risk to local (regional) conifers species is difficult to assess until further research is conducted.

Economic Impact: **Low**

Unless *S. laricis* introduces a highly pathogenic fungus, it is unlikely this species will cause serious economic impact in Minnesota. Because of its propensity to attack weakened pole size stands, branches, or slash it is unlikely to attack any material of economic value in Minnesota.

Host Specificity: **High**

Scolytus laricis is a relatively host specific bark beetle. In its native range, *S. laricis* is only recorded to occur in two *Larix* spp. and likely would only be capable of colonizing *Larix laricina* in Minnesota.

Potential for Associated Organisms: **Moderate**

As mentioned above, there is a serious threat of introduction of new fungi into Minnesota forests. In addition to possibly carrying associated fungi, many bark beetles also carry mites and other micro-organisms (Bridges et al. 1984; Stephen et al. 1993; Moser et al. 1997; Moser and Macías-Sámano, 2000).

Survey Potential: **Moderate**

Scolytus laricis develops under the bark, feeding in the phloem of host trees. However, this species could be identified in host tree material by the gallery pattern. The egg gallery is vertical, approximately 5 cm in length (Furniss and Johnson 2002) and likely would only be found on small-sized tree material (e.g., logs from tops of trees, small pole-sized material). The gallery pattern may be confused with that of *Scolytus piceae* (Swaine), which has been recorded to develop in branches of *Larix laricina* in Minnesota. Depending on what time of year logs or trees are moved, adult beetles could also be present and identifiable. Branches could be placed into rearing cages to determine if this species is present.

Pathway Potential: **Moderate**

As long as barked whole logs are imported into Minnesota for commercial purposes, it is likely that *S. laricis* will continue to be introduced into this region. However, because *S. laricis* is associated with smaller host tree material, the pathway potential may be more limited than other species of insects covered in this document. Logs imported for cabin home building, larch arabinogalactan, or other purposes that require small diameter tree material are introduction pathways for *S. laricis*.

Establishment Potential: **Moderate**

Scolytus laricis occurs in both *Larix* spp. that occur in its native range. While further research needs to be conducted to determine if *S. laricis* can reproduce in *Larix laricina*, it seems likely it could successfully reproduce in this tree species. Based on this assumption, it is likely *S. laricis* could become established in Minnesota.

Mitigation Potential: **Moderate**

Specific steps can be taken to reduce the likelihood that *S. laricis* will continue to be introduced into Minnesota. These options include:

1. Harvest trees after August and ship them promptly to Minnesota
2. Use trees that have been dead for more than 18 months.
3. Do not allow cut logs to be stored in western states during summer months when *S. laricis* colonizes trees before being shipped to Minnesota.
4. If found to be infested by *S. laricis* upon arrival in Minnesota, bark should be promptly removed and burned.
5. Log piles should be covered with tarps to reduce colonization and kill preexisting brood within logs.
6. Monitor log storage facilities with pheromone-baited traps.

Formicidae (Carpenter Ants)

Carpenter ants fill various roles (e.g., decomposition, predation, prey items) in forested ecosystems. However, carpenter ants also become problematic and colonize structures and other wood products, particularly in the northern US (Akre and Hansen 1990). Several exotic species of ants have caused serious economic and ecological problems in North America. The highly aggressive imported fire ant, *Solenopsis invicta*, has impacted local biodiversity (Wojcik et al. 2001). While carpenter ants are not as aggressive as *S. invicta*, they can cause changes in local insect community structure.

Camponotus noveboracensis (Fitch)

The carpenter ant, *Camponotus noveboracensis*, is a widespread species found throughout the northern US and is native to Minnesota (Figure 8). In Minnesota it has been recorded in northeastern parts of the state, including Duluth, Holyoke, Knife River, Knife Island, and Saganaga Lake (Gregg 1946). *Camponotus noveboracensis* is typically found in conifer or deciduous forests (Gregg 1946) where it nests in rotting logs and stumps (Bolton 1995). It has been found nesting in *Abies balsamea* and *Thuja occidentalis* (Sanders 1964). A survey of the specimens in the UMNIC revealed collection records from at least nine counties, including four from the northern half of the state. *Camponotus noveboracensis* can cause economic damage to seedling and/or saplings in forest regeneration areas by girdling rood collars of young trees (Furniss and Carolin 1977). However, *C. noveboracensis* has been recorded as a predator for several defoliating insects including spruce budworm (Sanders 1964), jack pine budworm (Allen et al. 1970), and forest tent caterpillar (Green and Sullivan 1950).

The mating flights for *Camponotus noveboracensis* occur in June (Sanders 1964). Female *Camponotus* spp. initiate colonies in logs, stumps, or soil where eggs are laid in groups of 9 to 16 (Hansen and Akre 1990). Workers from the initial batch of eggs emerge the first summer, eggs laid later overwinter in larval stages (Hansen and Akre 1990). *Camponotus* spp. colonies are dormant throughout most of the winter until the queen begins oviposition in late winter or early spring. Successful colonies begin to spread, creating satellite colonies relative to the parent colony and can cover areas up to 202 m^2 (Sanders 1964).

Overall Risk Rating: **Low**

Because native populations of *C. noveboracensis* occur in Minnesota and this species does not cause significant economic damage to forest resources, it is low risk to Minnesota forests. However, there could be unknown consequences of interbreeding of western and native Minnesota populations of *C. noveboracensis*.

Economic Impact: **Low**

Although *C. noveboracensis* has been recorded to cause some damage to tree seedling and saplings, this damage is likely minimal. When found in trees, *C. noveboracensis* can structurally weaken a tree, but it is usually responding to preexisting decay conditions. Unless western populations of *C. noveboracensis* behave differently than Minnesota populations, there should be no economic concern for this species.

Host Specificity: **Moderate**

Camponotus noveboracensis has been reported in several species of trees that occur in the Laurentian Mixed Forest Province. *Picea* spp., *Larix laricina*, *Abies balsamea*, and *Thuja occidentalis* L. have all been recorded as hosts for *Camponotus* spp. However, *C. noveboracensis* presence in these hosts is usually dependent on initial decay via fungi.

Potential for Associated Organisms: **Low**

While *C. noveboracensis* is commonly associated or found in areas where fungi have weakened wood, it is unknown if this species transfers fungi itself.

Survey Potential: **High**

Because *C. noveboracensis* is typically found in trees with decay, surveying for this species should concentrate on larger trees that have signs of decay. Adult *C.*

noveboracensis are easily recognizable and the galleries they create in rotted wood are easily determined.

<u>Pathway Potential: **Moderate**</u>

Western populations of *C. noveboracensis* will continue to be introduced into Minnesota as long as whole logs originating from mature forests come into the state. Older trees, like those transported into the state for log homes and larch arabinogalactan, are more likely to contain decay centers and *C. noveboracensis* colonies.

<u>Establishment Potential: **High**</u>

Because native populations of *C. noveboracensis* currently exist in Minnesota, it is likely western populations could become established in the state. Also, there is a high likelihood that western populations could interact with native *C. noveboracensis*.

<u>Mitigation Potential: **Moderate**</u>

Specific steps can be taken to reduce the likelihood that *C. noveboracensis* will continue to be introduced into Minnesota. These include:

1. Reduce the amount of mature timber that has signs of decay imported to Minnesota.
2. If mature, butt ends of logs are to be imported to Minnesota logs should be thoroughly checked for the presence of *C. noveboracensis* at the export site or at the harvest site. Sections with decay should be discarded.
3. If signs of *C. noveboracensis* (i.e., galleries, adults, larvae) are present in logs imported to Minnesota, portions of logs should be removed and burned.
4. Traps baited with ethanol can be used as a monitoring tool for dispersing females. Pitfall traps could be used to monitor for workers.

Conclusions

Ecological risk assessments can be useful in reducing introductions of damaging insects into new areas. They can also be used as a guide for monitoring or management efforts. This ecological risk assessment provides insights into potential problems of seven species of insects in the Laurentian Mixed Forest Province in northeastern Minnesota (Appendix 2). Mitigation options were included at the end of each risk rating.

There could be severe economic and ecological impacts associated with the introduction of western forest insect species into the Laurentian Mixed Forest Province. The woodborers will not cause serious economic losses, but ecologically they could prove problematic. Potential interactions with native populations, differences in associated fungi, or attacks on different host species could all impact Minnesota ecosystems. Economically, timber resources could be impacted by the introduction of scolytid beetles and associated fungi. Tamarack, an economically important tree species in Minnesota, is a likely host for both *D. pseudotsugae* and *S. laricis*. *Dendroctonus simplex* has caused wide spread loss of tamarack the past four years (Seybold et al. 2002), and *D. pseudotsugae* and *S. laricis* would likely cause further losses to these trees. If either scolytid becomes established, mortality to tamarack would be even greater than current levels. Further, if fungi associated with western scolytids become established and are more pathogenic in Minnesota conifers, it is likely native beetles cohabiting trees would become vectors of these fungi. For example, native elm beetles, *Hylurgopinus rufipes*, are known to carry the exotic Dutch elm disease fungi (Strobel and Lanier 1981).

Concerns over the interactions and interbreeding of western North American populations with native Minnesota populations have been discussed in this document. It is imperative that this be fully considered, as unknown consequences may occur when two allopatric populations come in contact and resume interbreeding. Specifically, changes in host breadth or insect behavior may occur and result in a potentially more aggressive insect that attacks more tree species in Minnesota.

Further research is needed to determine what organisms (e.g., fungi, yeast) are associated with the insects transported into Minnesota and the potential impact they will have on native trees. It is possible that associated organisms could pose the most serious threat to forests of Minnesota.

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Table 1. Preliminary List of Insect Specimens from *Larix occidentalis*, collected April 18, 2002, LAREX Plant Site, Cohasset, Minnesota.

Insect found	**No. of specimens**
Coleoptera	
Carabidae	
Stenolophus conjunctus Say	1
Staphylinidae	
Unidentified sp.	5
Unidentified sp.	8
Buprestidae	
Chrysobothris trinervia (Kirby)	10
Bostrichidae	
Stephanopachys substriatus (Paykull)	3
Cerambycidae	
Neoclytus muricatulus muricatulus (Kirby)	4
Phymatodes dimidiatus (Kirby)	1
Tetropium velutinum LeConte	2
Curculionidae	
Unidentified sp.	4
Miscellaneous	4
Hymenoptera/Coleoptera	
Hymenoptera	
Camponotus noveboracensis	1000's

Table 2 Preliminary List of Insect Specimens from Larix occidentalis, collected May 30, 2002, LAREX Plant Site, Cohasset, MN.

Insect found	**No. of specimens**
Coleoptera	
Carabidae	
Agonum gratiosum M.	1
Stenolophus comma F.	1
Staphylinidae	
Unidentified sp.	1
Buprestidae	
Phaenops drummondi (Kirby)	65
Bostrichidae	
Stephanopachys substriatus (Paykull)	5*
Trogossitidae	
Temnochila chlorodia	21
Cerambycidae	
Pygoleptura nigrella (Say)	1
Phymatodes dimidiatus (Kirby)	12
Tetropium velutinum LeConte	46
Xylotrechus longitarsus Casey	1
Curculionidae	
Unidentified sp.	1
Unidentified sp.	1
Scolytidae	
Scolytus laricis	39 (16 , 23)
Dendroctonus pseudotsugae	4**
Polygraphus rufipennis	1
Miscellaneous Hymenoptera, Coleoptera, and Lepidoptera	12

*One additional *Stephanopachys substriatus* was collected February 13, 2004.

** Six additional *Dendroctonus pseudotsugae* were collected from beneath the bark of *Larix occidentalis* February 13, 2004.

Table 3. List of common and scientific names for tree species referred to in this document.

Common Name	**Scientific Name**
Balsam fir	*Abies balsamea* (L.) Mill.
Tamarack	*Larix laricina* (Du Roi) K. Koch
Western larch	*Larix occidentalis* Nutt.
White spruce	*Picea glauca* (Moench) Voss
Black spruce	*Picea mariana* (Mill.) B. S. P.
Jack pine	*Pinus banksiana* Lamb.
Western white pine	*Pinus monticola* Dougl. ex D. Don
Red pine	*Pinus resinosa* Ait.
White pine	*Pinus strobus* L.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Northern white cedar	*Thuja occidentalis* L.

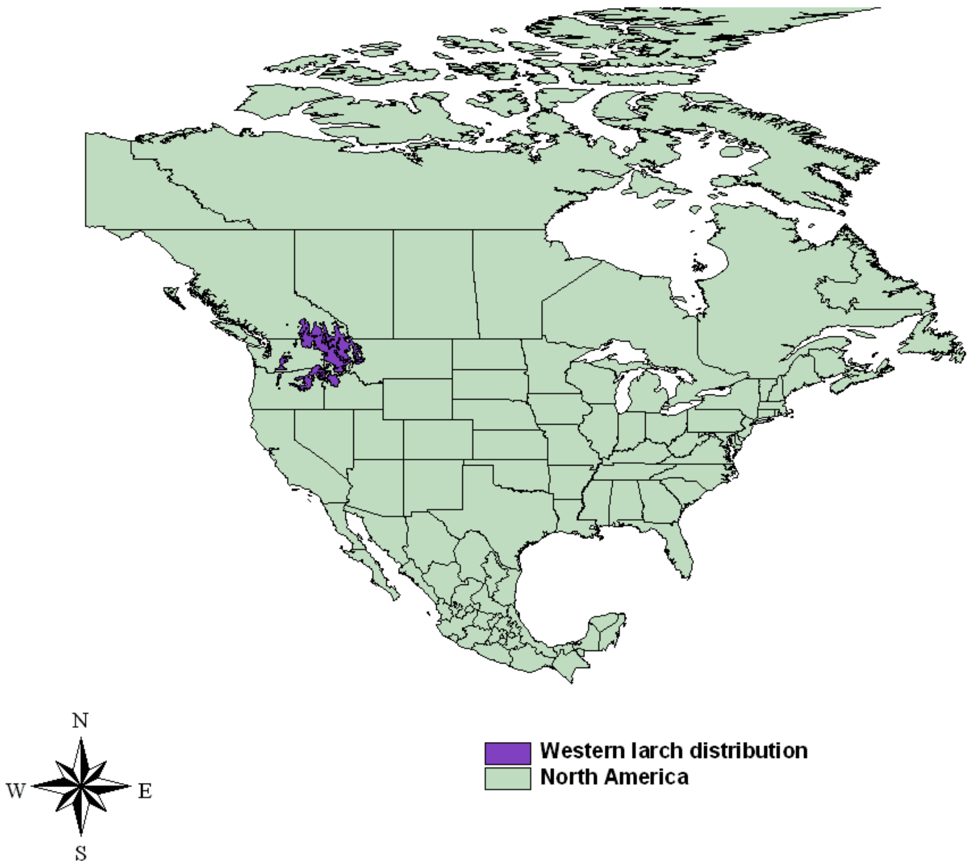

Figure 1. Distribution of western larch in North America.

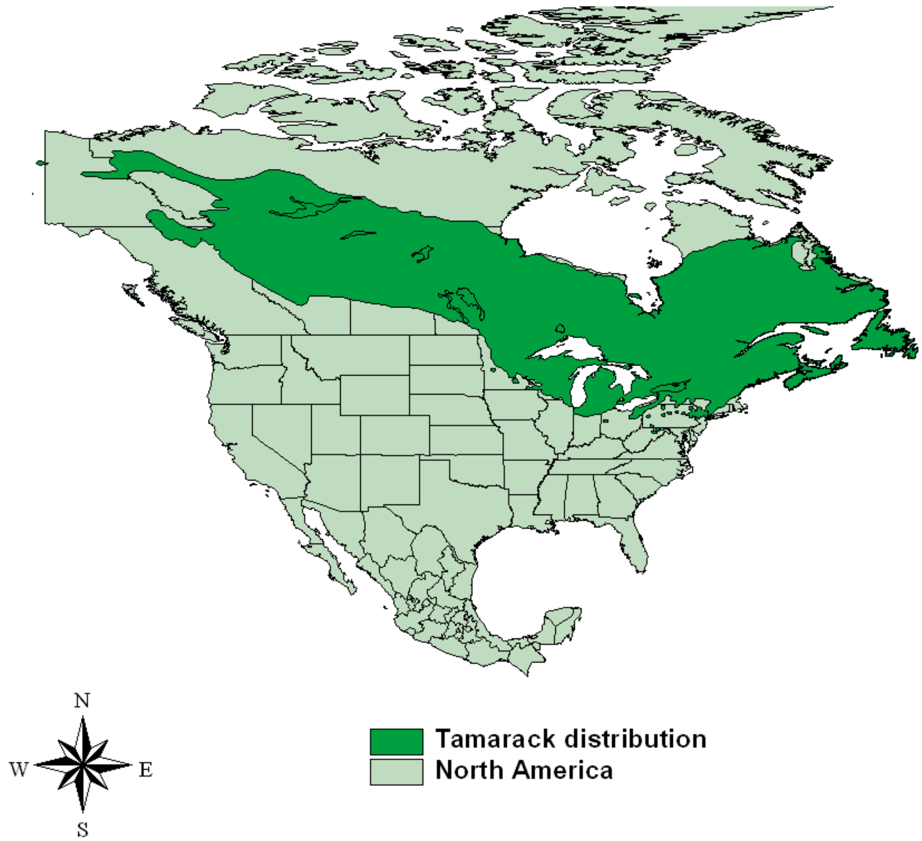

Figure 2. Distribution of tamarack in North America.

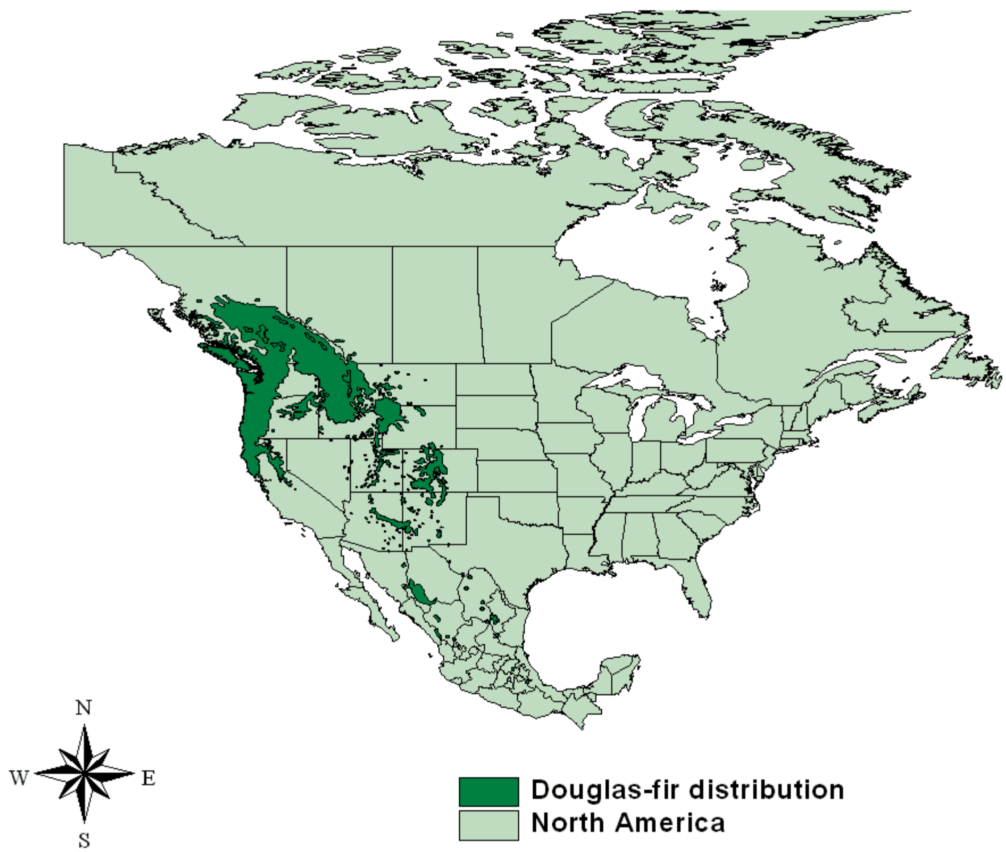

Figure 3. Distribution of Douglas-fir in North America

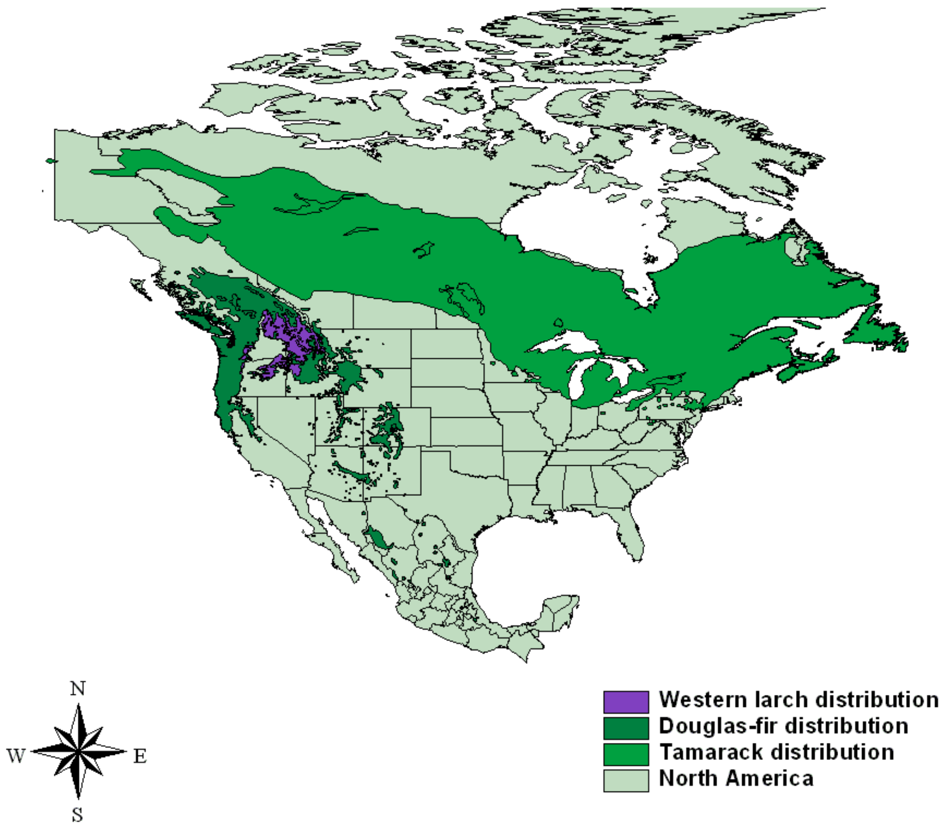

Figure 4. The distributions of western larch, Douglas-fir, and tamarack in North America.

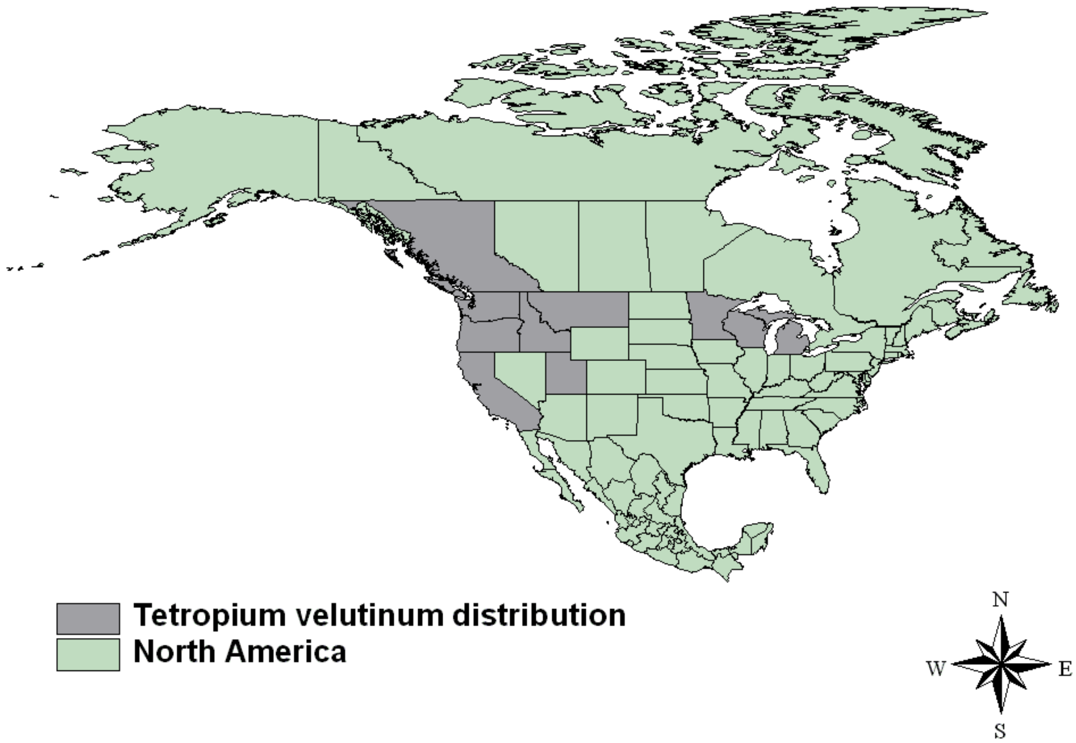

Figure 5. Species distribution for *Tetropium velutinum* in the United States. Note: species may occur in only a portion of each state.

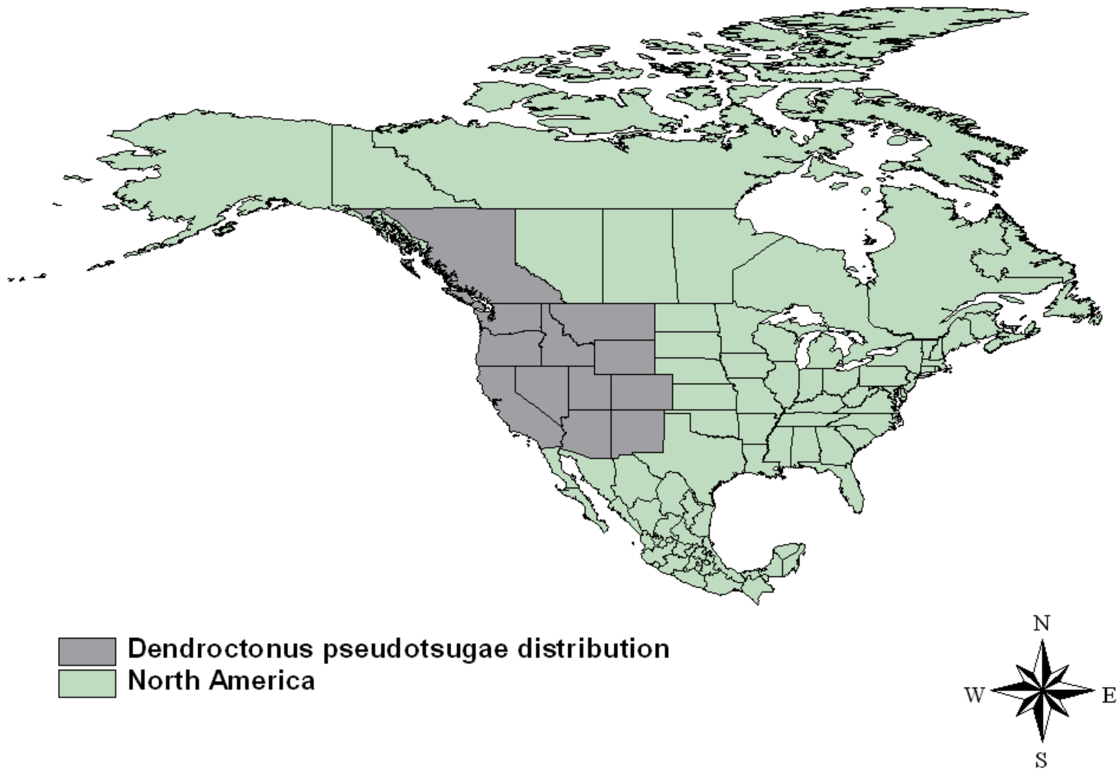

Figure 6. Species distribution for *Dendroctonus pseudotsugae* in the United States. Note: species may occur in only a portion of each state.

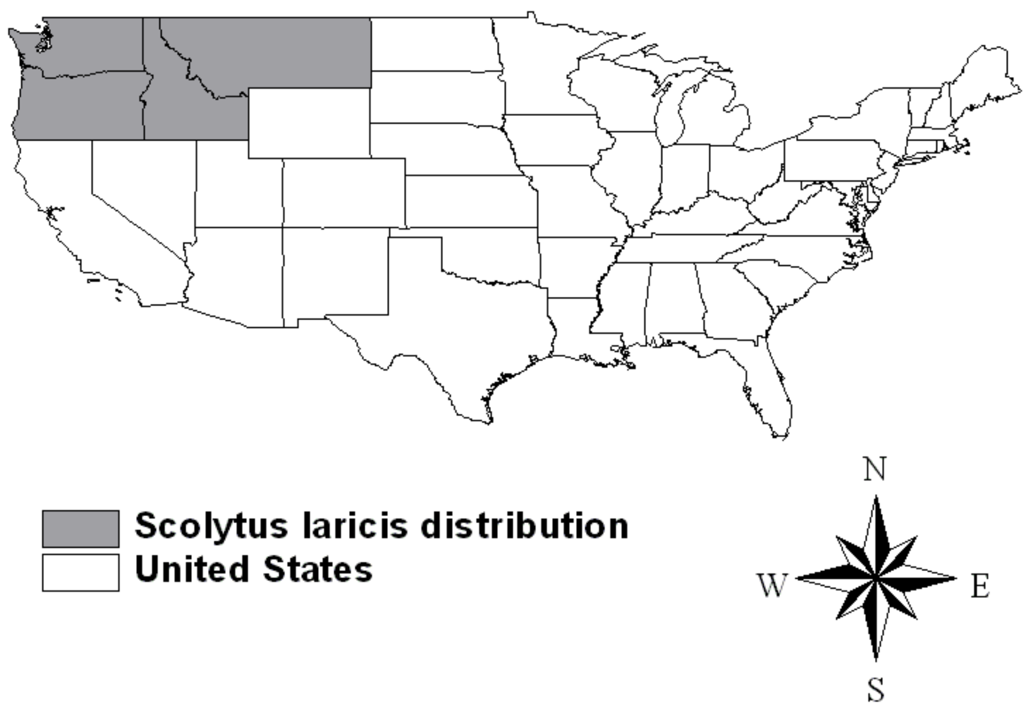

Figure 7. Species distribution for *Scolytus laricis* in the United States. Note: species may occur in only a portion of each state.

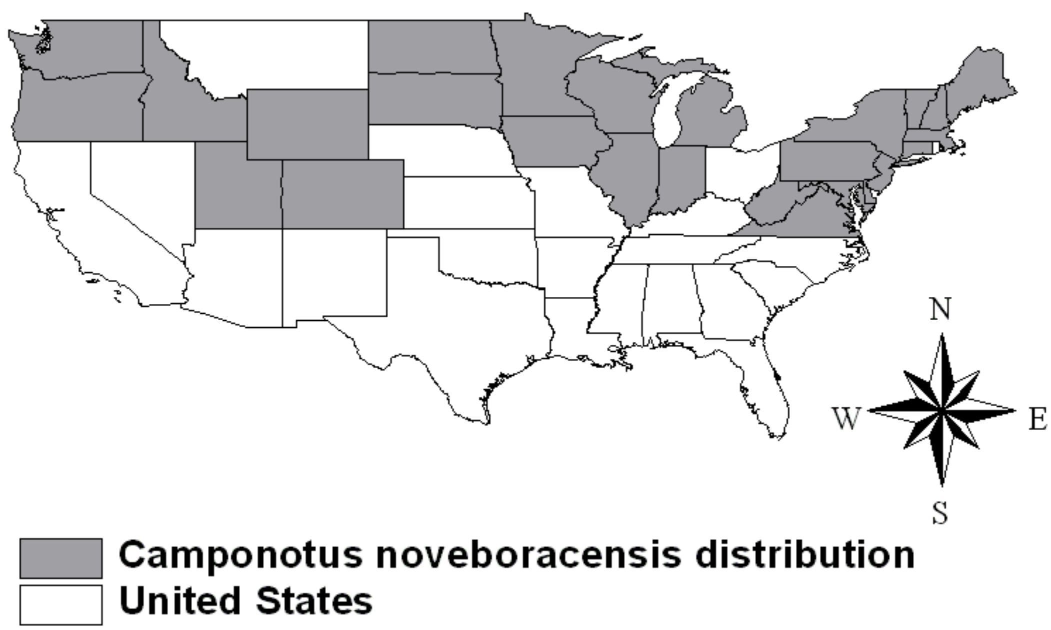

Figure 8. Species distribution for *Camponotus noveboracensis* in the United States. Note: species may occur in only a portion of each state.

Appendix 1

Overall Risk Rating

Rating	Description
Low	– Insect does not attack and kill living trees – Associated organisms are minimal or non existant – Already present in ecosystem
Moderate	– Insect does not typically attack and kill living trees – Associated organisms are minimal – Associated organisms may or may not be a concern themselves
High	– Kills apparently healthy trees – Primary tree killer – Carries associated organisms that are a risk themselves – New to ecosystem

Economic Impact

Rating	Description
Low	– Occurs in dead trees or trees of little economic value – Usually does not affect the sapwood of trees – Inhabits small trees, tree tops, or branches that are not typically imported
Moderate	– Usually occurs in dead trees – May colonize living trees weakened by disturbance – Always enters sapwood of host trees
High	– Kills economically important tree species – Aggressive insect – Extensively damages sapwood

Host Specificity

Rating	Description
Low	– Found in many species of trees (>3 species)
Moderate	– Found in only a few species of trees (2-3 species)
High	– Found only in 1 tree species

Potential for Associated Organisms

Rating	Description
Low	– Not known to carry associated organisms
Moderate	– Carries associated organisms – Not known to be pathogenic in native ecosystem. – Related insect species known to carry associated organism
High	– Carries associated organisms – Known to be highly pathogenic in native ecosystem

Survey Potential

Rating	Description
Low	– Cryptic species found under the bark or in sapwood at time log material is transported – Bark must be removed to locate galleries or sapwood entrance holes
Moderate	– Found under bark, not in sapwood – Identity easy to determine from gallery or larvae
High	– Adults easily distinguishable and present in wood – Keys or guides exist to identify species

Pathway Potential

Rating	Description
Low	– Rare that tree material would be moved at a time that coincides with an insects presence – Tree material imported in a form that would not have insects (e.g., debarked logs)
Moderate	– Wood transported when insects are present – Insect occurs in parts of tree that are not commonly imported – Pathway not commonly used
High	– Wood transported when insects are present – Pathway is frequently used

Establishment Potential

Rating	Description
Low	– Likelihood insect could survive winter temperature is low – Unlikely to find a suitable host – Low numbers of individuals introduced, therefore unlikely to establish a population
Moderate	– Insect can survive winter temperatures – Likely to find a suitable host – Potential to be introduced in large enough numbers to establish a population.
High	– Native populations exist – Insect can survive winter temperatures – Large enough populations coming in to establish a population

Mitigation Potential

Rating	Description
Low	– No options available for stopping the introduction of insect into forests – No known technologies that can be implemented to monitor and manage the species
Moderate	– Possible to reduce introductions – Known and reliable survey technologies presently exist.
High	– Possible to reduce introductions through cultural controls – Known and reliable survey technologies presently exist – Management technologies presently exist.

Appendix 2. Summary table of the seven ecological risk ratings created for forest insects reared from *Larix occidentalis* logs imported into northern Minnesota.

Species	**Overall Risk Rating**	**Economic Impact**	**Host Specificity**	**Potential for Associated Organisms**	**Survey Potential**	**Pathway Potential**	**Establishement Potential**	**Mitigation Potential**
Tetropium velutinum LeConte	Moderate	Low	Low	Moderate	Low	High	High	Moderate
Pygoleptura nigrella (Say)	Low	Low	Low	Low	Low	High	Moderate	Moderate
Phaenops drummondi (Kirby)	Low	Low	Low	Low	Low	High	High	Moderate
Stephanopachys substriatus (Paykull)	Low	Low	Low	Low	Low	Moderate	High	Moderate
Dendroctonus pseudotsugae Hopkins	High	High	High	High	Moderate	High	Moderate	High
Scolytus laricis Blackman	Moderate	Low	High	Moderate	Moderate	Moderate	Moderate	Moderate
Camponotus noveboracensis (Fitch)	Low	Low	Moderate	Low	High	Moderate	High	Moderate