Mini Risk Assessment
Siberian Silk Moth, *Dendrolimus superans* Butler
[Lepidoptera: Lasiocampidae]

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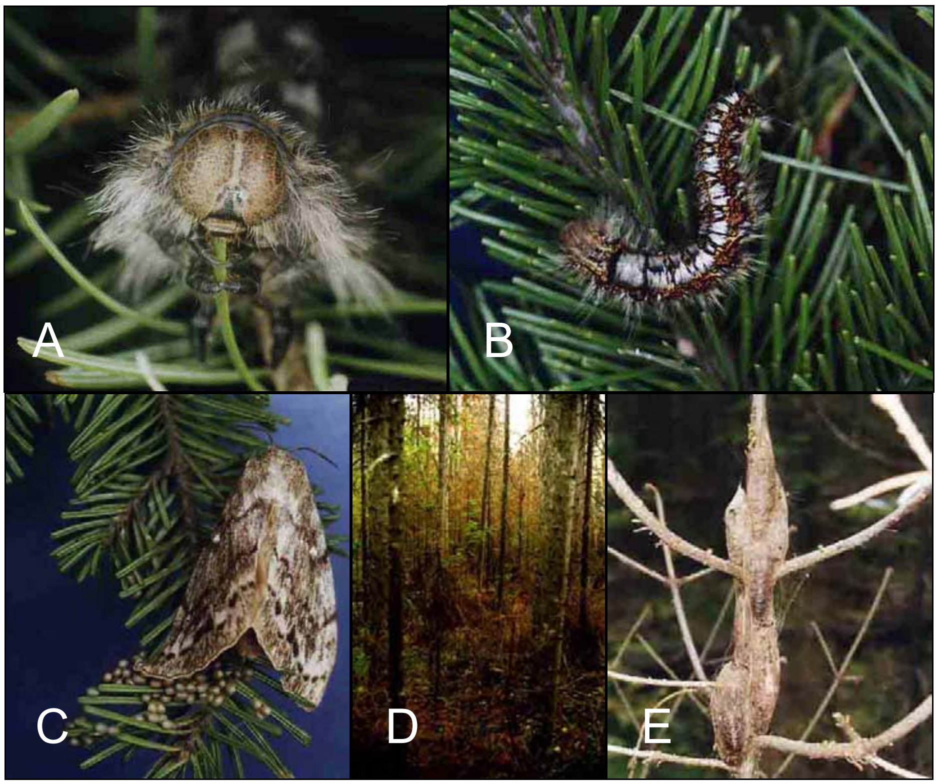

Figure 1. *Dendrolimus superans*: (A) feeding larva; (B) fifth instar larva; (C) egg-laying adult; (D) stand defoliation one year after outbreak; and (E) pupae. Images not to scale. [Source: Krasnoyarsk Center for Forest Protection (KCFP 2004).]

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Introduction
Dendrolimus superans Butler, is a major pest of conifers in the Palearctic where it is adapted to survive cold and semi-arid conditions (Zhang 1994, Baranchikov et al. 1997, CFIA 2001, Baranchikov 2002, EPPO 2005b). *Dendrolimus superans* occurs throughout much of Asia, particularly in Asian Russia and the far East, and in eastern Europe (Poland) but is not known to occur in the United States (Zhang 1994, CAB 2004). This lasiocampid moth has several common names including, the Siberian silk moth, the Siberian moth, and larch caterpillar (CAB 2004). There is significant disagreement about the true identity of the species and its proper scientific name (see Taxonomic Recognition). In this document, we treat *D. superans*, *D. sibiricus*, *D. superans sibiricus*, and *D. superans albolineatus* as a single species. Mention of *D. sibiricus* in the text is simply intended to convey the exact taxon mentioned in an original source of information.

The risks posed by *D. superans* have been evaluated previously in slightly different contexts. In the Exotic Forest Pest Information System, Orlinski (2000) considered establishment of *D. sibiricus* in North America to be highly likely and the ecological and economic impacts to be high; but this assessment was uncertain. In an assessment for potential imports of Siberian larch into the US, *D. sibiricus* was identified as a potential hitchhiker with a medium likelihood of being associated with the host on any given shipment, a high transport potential, a high probability of surviving shipment, a medium establishment potential, a medium colonization potential, and a high loss potential (USDA 1991). The purpose of this "mini-" pest risk assessment is to further evaluate several factors that contribute to risks posed by *D. superans* and apply this information to the refinement of sampling and detection programs.

1. **Ecological Suitability. Rating: High.** *Dendrolimus superans* is present throughout much of Asia, particularly in Asian Russia and the Far East, excluding extreme northern regions (i.e., north of 62° N latitude) (Rozhkov 1970, Kolomiets 1995). *Dendrolimus superans* has also been reported in Poland but, to date, has not been reported elsewhere in Europe. Appendix A provides a detailed list of countries reporting this insect. In general, *D. superans* occurs in semi-arid to humid, and temperate to cold climates. The currently reported distribution of *D. superans* suggests that the pest may be most closely associated with biomes characterized as: boreal forests; temperate grasslands, savannas and shrublands; temperate broadleaf and mixed forests; temperate coniferous forests; montane grasslands, and treeline areas of tundra. Of these biomes, only temperate

grasslands, savannas and shrublands, temperate coniferous forests and temperate broadleaf and mixed forests occur in the US. Consequently, we estimate that approximately 79% of the continental US would have a suitable climate for *D. superans* (Fig. 2). See Appendix A for a more complete description of this analysis.

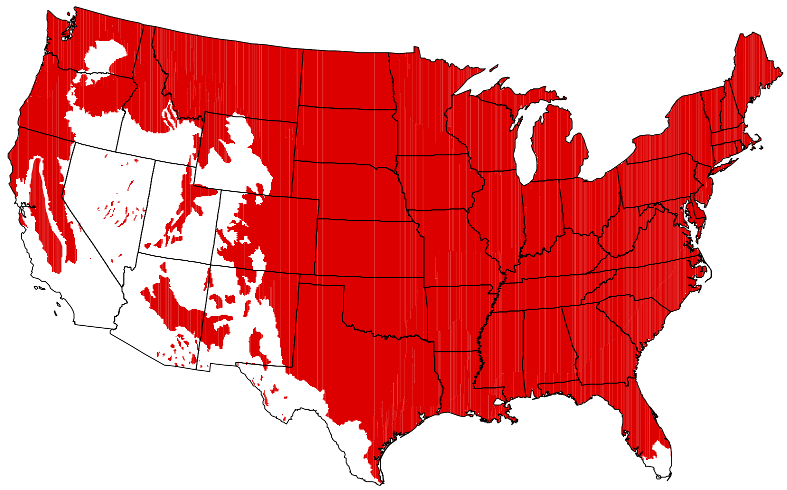

Figure 2. Predicted distribution (shaed red) of *Dendrolimus superans* in the contiguous US.

Figure 2 illustrates where *D. superans* is most likely to encounter a suitable climate for establishment within the continental US. This prediction is based only on the known geographic distribution of the species. Because this forecast is based on coarse information, areas that are not highlighted on the map may have some chance of supporting populations of this exotic species. However, establishment in these areas is less likely than in those areas that are highlighted. Initial surveys should be concentrated in the higher risk areas and gradually expanded as needed.

2. **Host Specificity/ Host Availability. Rating: Moderate/Low**. *Dendrolimus superans* is moderately host specific. The insect reportedly feeds on over 20 coniferous species, but all known hosts occur within the family Pinaceae (Table 1). Although many of the same host genera occur in Asia and the US, none of the reported host species are common in the US, except perhaps in ornamental settings. For *D. sibiricus* to invade the US, it would have to feed upon species that it has not encountered previously. The susceptibility of US species has yet to be determined.

Table 1. Host plants of *Dendrolimus superans* (organized by common name).

Hosts	**References**
cedar, deodar (*Cedrus deodara*)	(Kamata 2002)
cedar[2] (*Cedrus* sp.)	(CAB 2003)
fir (*Abies* sp.)	(Baranchikov et al. 1997, Baranchikov 2002)
fir[1] (*Abies* sp.)	(McBride 2000, Khrimian et al. 2002)

Hosts	References
fir[2] (*Abies* sp.)	(Nedorezov 1981, Gninenko and Orlinskii 2002, Konefal and Karnkowski 2003, Ranson et al. 2004, EPPO 2005a)
fir, Manchurian (*Abies holophylla*)	(CFIA 2001)
fir, Manchurian[2] (*Abies nephrolepis* (=*A. gracilis*))	(EPPO 2005a)
fir, Sakhalin (*Abies sachalinensis*)	(CFIA 2001, Kamata 2002)
fir, Siberian (*Abies sibirica*)	(CFIA 2001)
fir, Siberian[1] (*Abies sibirica*)	(Klun et al. 2000, Baranchikov 2002, Grodnitsky and Raznobarskii 2002)
fir, Siberian[2] (*Abies sibirica*)	(Konikov and Aleksandrina 1978, Ierusalimov 1979, Kharuk et al. 1997, EPPO 2005a)
hemlock, Southern Japanese (*Tsuga sieboldii*)	(Zhang 1994)
hemlock[2] (*Tsuga* sp.)	(Gninenko and Orlinskii 2002, EPPO 2005a)
larch (*Larix* sp.)	(Yu and He 1987, Zhang 1994, Meng et al. 1995, Baranchikov et al. 1997, CFIA 2001, Deng et al. 2002, CAB 2003)
larch, Dahurian (*Larix gmelinii* (*gmelin*))	(Tian et al. 1998, Kong et al. 2001)
larch, Dahurian[2] (*Larix gmelinii* (=*L. dahurica*))	(CAB 2003, EPPO 2005a)
larch, Japanese (*Larix kaempferi*)	(CAB 2003)
larch, Prince Rupprecht Dahurian (*Larix gmelinii* var. *principis*)	(CFIA 2001)
larch, Siberian (*Larix sibirica*)	(CFIA 2001)
larch, Siberian[1] (*Larix sibirica* (=*L. sukaczevii*))	(Klun et al. 2000, Khrimian et al. 2002)
larch, Siberian[2] (*Larix sibirica* (=*L. sukaczevii*))	(Zhang 1994, Kharuk et al. 1997, EPPO 2005a)
larch[1] (*Larix* spp.)	(McBride 2000, Baranchikov 2002, Khrimian et al. 2002)
larch[2] (*Larix* spp.)	(Zrazhevskaya and Girs 1988, Gninenko and Orlinskii 2002, CAB 2003, Gninenko and Sidel'nik 2003, Konefal and Karnkowski 2003, EPPO 2005a)
pine (*Pinus* sp.)	(Zhang 1994, Baranchikov et al. 1997, CFIA 2001, Li et al. 2002, CAB 2003, Zhang et al. 2004)
pine[2] (*Pinus* sp.)	(Zhang 1994, Gninenko and Orlinskii 2002, EPPO 2005a)
pine, Japanese black (*Pinus thunbergii*)	(CFIA 2001)
pine, Korean (*Pinus koraiensis*)	(CFIA 2001)
pine, Korean[2] (*Pinus koraiensis*)	(EPPO 2005a)
pine, Scots (*Pinus sylvestris*)	(CFIA 2001)
pine, Scots[2] *(Pinus sylvestris)*	(CAB 2003)
pine, Siberian (*Pinus sibirica*)	(Baranchikov et al. 1997, CFIA 2001)

Hosts	References
pine, Siberian[1] (*Pinus sibirica*)	(Baranchikov 2002)
pine, Siberian[2] (*Pinus sibirica*)	(Ierusalimov 1979, Kharuk et al. 1997, Gninenko and Orlinskii 2002, Konefal and Karnkowski 2003, Ranson et al. 2004, EPPO 2005a)
spruce (*Picea* sp.)	(Baranchikov et al. 1997)
spruce[1] (*Picea* spp.)	(McBride 2000, Baranchikov 2002)
spruce[2] (*Picea* spp.)	(Gninenko and Orlinskii 2002, Konefal and Karnkowski 2003, EPPO 2005a)
spruce, hondo (*Picea jezoensis* var. *hondoensis*)	(Kamata 2002)
spruce, Siberian (*Picea obovata*)	(CFIA 2001)
spruce, Siberian[2] (*Picea obovata*)	(Ierusalimov 1979, Kharuk et al. 1997, EPPO 2005a)
spruce, yeddo (*Picea jezoensis*)	(CFIA 2001, CAB 2003)
spruce, yeddo[2] (*Picea ajanensis* (=*P. jezoensis*))	(EPPO 2005a)

1. Reported host plants of *Dendrolimus superans sibiricus*.
2. Reported host plants of *Dendrolimus sibiricus*.

Unlike other mini-pest risk assessments that we have produced, we do not provide maps showing where hosts are grown because (a) known host species do not occur widely in the US and (b) the number of potential hosts in the US is tremendous.

3. **Survey Methodology. Rating: High.** A modified beat sampling technique ("okolot" in Russian) has been used in the Russian Far East to monitor populations of *D. superans* (Vartanov 2002). The "kolot" refers to a large "hammer" or log (2.5-3m) that is used to strike a tree and dislodge larvae. A site around a suspect tree is prepared by clearing all understory vegetation and spreading a tarp at the base. A tree is struck 6-8 times with the kolot and larvae on the tarp are identified and counted (Vartanov 2002). With experienced labor, ten trees may be sampled in 0.7 d, including the time to prepare the kolot (Vartanov 2002).

   Monitoring populations with pheromone-baited traps is a far more cost effective approach than beat sampling (Vartanov 2002). A 1:1 blend of aldehydes [64% (*Z,E*)-5,7-dodeceadienal; 10% (*Z*)-5-dodecenal; 18% (*E*)-7- dodecenal; 8% (*E*)-6-dodecenal] and alcohols [64% (*Z*,*E*)-5,7-dodecadien-1-ol; 10% (*Z*)-5-dodecen-1-ol; 18% (*E*)-7-dodecen-1-ol; 8% (*E*)-6-dodecen-1-ol] will capture as many males moths as a virgin female (Klun et al. 2000). Kong et al (2001) suggest that a 1:1 mixture of (*Z,E*)-5,7-dodeceadienal and (*Z*,*E*)-5,7-dodecadien-1-ol is adequate to attract males. Khrimian et al. (2002) confirm this result in the field and demonstrate that this mixture attracts males as effectively as virgin females.

Grey rubber septa (1x2 cm; West Co., Kearney NE) are pre-cleaned with acetone and "treated with 12.2 µl of a solution containing 164 µg of a 1:1 mixture of [(*Z,E*)-5,7-dodeceadienal] and [(*Z*,*E*)-5,7-dodecadien-1-ol] per 1 µl of heptane (2mg of sex attractant/septum)" (Khrimian et al. 2002). Loaded septa can be stored at -80°C for 2 weeks without a reduction in attractiveness (Khrimian et al. 2002). Septa are placed inside modified USDA milk carton type traps, originally designed for gypsy moth (Klun et al. 2000). Traps should be modified by expanding entrance holes to 7cm wide x 3 cm high (Klun et al. 2000) or 2.5 x 3.0 cm (Khrimian et al. 2002). Vapona© strips at the bottom of the trap will kill all incoming insects (Klun et al. 2000, Khrimian et al. 2002). Traps should be 1.5 m (5 ft) above the ground when hung in trees (Klun et al. 2000, Khrimian et al. 2002). In Russia, traps are placed every 500 m (0.3 mi) (Vartanov 2002).

Figure 3. Modified milk-carton type trap baited with pheromone for the detection of *Dendrolimus superans* [Image from A. Tyskalov, http://www.forestproject.ru/web2/pests/pests.htm]

During severe outbreaks when >50% of trees are defoliated, suspect areas can be identified by remote sensing (Kharuk et al. 1997). Imagery from NOAA/AVHRR reliably detected infestations >1.1 km on the ground. Ground truthing is necessary to confirm the presence of *D. superans*.

4. **Taxonomic Recognition. Rating: Medium-High.** *Dendrolimus superans* may occur in mixed populations with closely related or other easily confused species (primarily *D. pini*) on similar hosts within its native range (EPPO 2005a). *Dendrolimus pini* is also not known to occur in the United States. *Dendrolimus superans* is sufficiently unique that it should be readily identified in the field, but a qualified taxonomist should be consulted to confirm species identity.

   For a detailed description of the morphology and taxonomy of *D. superans*, see Appendix B.

5. **Entry Potential. Rating: Low.** *Dendrolimus superans* is most likely to be transported into the United States in infested plant material. Larvae feed on

foliage; eggs masses are laid in clusters on needles and branches; pupae occur in sheltered areas such as branch collars in close proximity to the main trunk of a host tree (EPPO 2005a). Thus, known hosts [see 'Host Specificity'] from infested countries have the potential to harbor this insect. Moths and larvae may be distinguished morphologically from other species but may be difficult to detect during routine quarantine inspections at ports of entry (EPPO 2005a). Thus, previous interception records of the pest may not accurately characterize the frequency at which this pest actually arrives in the US.

A single interception of "*Dendrolimus* sp." was reported in 1984 from Honolulu on pine (*Pinus* sp.) in passenger baggage from Japan (USDA 2005). *Dendrolimus* spp. may have arrived in the US slightly more frequently than suggested by this record. Specimens identified as "Lasiocampidae" are actionable, and no further identification would be needed to make a regulatory decision. Specimens identified as "Lasiocampidae" have been intercepted at least 20 times at US ports of entry between 1985 and 2004 (incomplete records complicate the accuracy of this count). Annually, only about 0.8 (±0.24 standard error of the mean) interception has been reported nationally (USDA 2005). The majority of interceptions (35%) were considered 'at large' or loosely associated with unspecified plants or wood. The majority of interceptions were reported from Miami, FL (20%), Laredo, TX (10%), and JFK International airport, NY (10%). These ports are the first points of entry for infested material coming into the US and do not necessarily represent the final destination of infested material. Movement of potentially infested material is more fully characterized in the next section. Specimens only identified to the family level may not be *Dendrolimus* spp., so inferences must be drawn carefully from these records. However, even if all Lasiocampidae records were of *Dendrolimus*, the annual rate of arrival would still be considered extremely low compared with other pests.

Although we assign a low rating to the potential for entry, we recognize that not all pathways for the introduction of forest pests have been studied with any detail. Consequently, a great deal of uncertainty is associated with our rating.

6. **Destination of Infested Material. Rating: Low.** When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. The single interception of *Dendrolimus* sp. was destined for Hawaii (USDA 2005). Materials infested with "Lasiocampidae" were destined for 8 states. The most commonly reported destinations were Florida and California (25% each), Texas (10%), and New York (10%) (USDA 2005). Some portion of each of state identified as the intended final destination has a climate and hosts that would be suitable for establishment by *Dendrolimus superans*.

7. **Potential Economic Impact. Rating: High.** *Dendrolimus superans* is an economically important defoliator of coniferous forests in Asia. During outbreak years, larvae of this lasiocampid kill thousands to millions of hectares of forests. Population density of *D. superans* typically builds up over a period of several

years, reaches an outbreak condition, and then collapses. Outbreaks have been reported in China since the late 14th Century; in Russia since 1870 (particularly Asian and Siberian Russia and the Russian Far East), and in Japan, Mongolia, Poland, and North and South Korea (Rozhkov 1970, Yang and Gu 1995, Baranchikov et al. 1997, Allard 1998, Selikhovkin 2000, CFIA 2001, Deng et al. 2002, Gninenko and Orlinskii 2002, Kamata 2002, Zhang et al. 2004, EPPO 2005a). *D. superans* outbreaks have been reported in pine, fir, spruce and larch forests, and vary in size and extent depending on factors including population density, dispersal behavior, forest type, and host availability (Baranchikov et al. 1997, Baranchikov 2002). In larch forests, an outbreak may have a greater duration, but overall extent of damage may be less severe than in fir or pine because larch is more tolerant to defoliation (Baranchikov et al. 1997, Baranchikov 2002). Outbreaks typically occur every 8-11 years and last 2-3 years (Baranchikov et al. 1997, EPPO 2005a). Weakened, stressed trees are subject to attack by secondary pests, and areas of large-scale tree mortality are vulnerable to forest fires (EPPO 2005a). Repeated annual defoliation can result in tree mortality. Since 1873, 10 outbreaks have occurred in central Siberian forests comprised largely of fir. Extensive mortality during these outbreaks was due either directly to repeated defoliation, or indirectly due to secondary causes including fir sawyer beetle damage and forest fire (CFIA 2001, Baranchikov 2002).

Establishment of *D. superans* in the US could have adverse impacts on domestic and international trade. *Dendrolimus superans* (and *D. sibiricus*) were elevated to A2 quarantine status in 2005 (EPPO 2005b). A2 status recognizes that the species is present, but with a limited distribution, in a European-and-Mediterranean-Plant-Protection-Organization member nation. Establishment of *D. superans* would likely result in domestic and/or international quarantines or requirements for additional treatment of potentially infested host materials (EPPO 2005b).

8. **Potential Environmental Impact. Rating: High.** In general, newly established species may adversely affect the environment by reducing biodiversity, disrupting ecosystem function, jeopardizing endangered or threatened plants, degrading critical habitat, or stimulating use of chemical or biological controls. *Dendrolimus superans* is likely to affect the environment in many of these ways.

   Dendrolimus superans has a moderate host range, feeding primarily on needles and tender new growth of coniferous hosts [see 'Host Specificity']. However, 82% of forests in the western US are coniferous, so the potential for large-scale impact on forest composition is tremendous (Baranchikov 2002). In Russia, outbreaks of *D. superans* have been severe enough to alter physicochemical soil properties and fundamental ecosystem processes (Krasnoshchekov and Vishnyakova 2003). Specifically, invasion of *D. sibiricus* lowers the amount of plant material that reaches the forest floor and significantly increases the amount of frass and other "zoogenic falloff." Frass stimulates soil organisms and speeds mineralization of organic matter. Water soluble compounds leach from the soil or are captured by herbaceous vegetation. Extensive growth of herbaceous plants intensifies humus accumulation and alters forest successional processes, fire regimes, and regeneration cycles (Krasnoshchekov and Vishnyakova 2003).

Furthermore, *D. superans* may adversely affect legally-protected species. Appendix C summarizes federally listed threatened or endangered plant species (USDA 2001) found within plant genera known to be hosts (or potential hosts) for *D. superans*. Plants listed in Appendix D might be suitable hosts for *D. superans*, and thus, could be adversely affected by this insect.

Outbreaks across Asia have stimulated the use of aerial applications of synthetic pyrethroids or naturally-derived insecticidal compounds for insect suppression (Baranchikov et al. 1997, Deng et al. 2002, EPPO 2005a). Following an outbreak of *D. superans* in the Democratic People's Republic of Korea in 1996, an emergency aerial application of *Bt* var. *kurstaki* was applied to forest areas of Ryanggang Province (Allard 1998). *Bt* is generally considered host specific (Lacey and Siegel 2000), but some exceptions have been noted, especially after repeated applications (Lacey and Siegel 2000, Boulton 2004). Several natural enemies have been identified for *D. superans* (EPPO 2005b), and these could be pursued for classical biological control in the US.

9. **Establishment Potential. Rating: High.** Much of the United States has a suitable climate and host plants that would be suitable for establishment of *D. superans* if it were introduced. A high rating is warranted. However, we note that the likelihood of *D. sibiricus* being introduced appears to be low based on interception records. Conceivably, eggs could be associated with the bark of raw logs or other plant materials. Because of their small size, eggs could be missed during routine inspections. As a result, a considerable degree of uncertainty is associated with the rating for this element.

   See Appendix D for a more detailed description of the biology of *D. superans*.

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Appendix A. Geographic distribution and comparison of climate zones. To determine the potential distribution of a quarantine pest in the US, we first collected information about the worldwide geographic distribution of the species (Table A1). Using a geographic information system (e.g., ArcView 3.2), we then identified which biomes (i.e., habitat types), as defined by the World Wildlife Fund (Olson et al. 2001), occurred within each country or municipality reported An Excel spreadsheet summarizing the occurrence of biomes in each nation or municipality was prepared. The list was sorted based on the total number of biomes that occurred in each country/municipality. The list was then analyzed to determine the minimum number of biomes that could account for the reported worldwide distribution of the species. Countries/municipalities with only one biome were first selected. We then examined each country/municipality with multiple biomes to determine if at least one of its biomes had been selected. If not, an additional biome was selected that occurred in the greatest number of countries or municipalities that had not yet been accounted for. In the event of a tie, the biome that was reported more frequently from the entire species' distribution was selected. The process of selecting additional biomes continued until at least one biome was selected for each country. Finally, the set of selected biomes was compared to those that occur in the US.

Table A1. Reported geographic distribution of *Dendrolimus superans*.

Locations	**References**
China	(CFIA 2001)
China (Heilongjiang Province - Huachuan)	(Yu and He 1987)
China (Heilongjiang Province - Longjiang)	(Yu and He 1987)
China (Heilongjiang Province - Nehe City)	(Deng et al. 2002)
China (Heilongjiang Province - Shangzhi)	(Yu and He 1987)
China (Heilongjiang Province - Shibazhan, Huma, Xinlin, Songling, Qiqihar, Yichun, Jamusi, Bei'an, Dedu, Dailing)	(Yue et al. 1996)
China (Heilongjiang Province -Huanan county)	(Yu and He 1987, He 1989)
China (Heilongjiang Province)	(CAB 2003)
China (Inner Mongolia (Chifeng))	(Li et al. 2002)
China (Inner Mongolia (Chuoyuan Region))	(Yue et al. 1996)
China (Inner Mongolia (Daxingan Mts.))	(Yue et al. 1996)
China (Inner Mongolia (Yakshi forest district))	(Tian et al. 1998)
China (Jilin)	(CAB 2003)
China (Liaoning Province - Kezuo)	(Zhang and Zheng 1988)
China (Liaoning Province - Xifeng county)	(Kong et al. 2001, Zhang et al. 2004)
China (Liaoning Province)	(Zhang 1994, CAB 2003)
China (northeast)	(Yu and He 1987, Deng et al. 2002)
China (Xinjiang)	(Yang and Zhao 1987)
China[1]	(Rozhkov 1970)
China[1] (Daxinganling Mountains)	(Yang and Gu 1995)
China[1] (northeast)	(Rozhkov 1970)
China[2]	(Nedorezov 1981, Allard 1998)
China[2] (Heilongjiang)	(CAB 2003)

Locations	References
Japan	(Zhang 1994, CFIA 2001)
Japan (Hokkaido - Kitami district)	(Maeto 1991)
Japan (Hokkaido)	(Kamata 2002, CAB 2003)
Japan (Honshu)	(Maeto 1991, Kamata 2002)
Japan[2]	(Nedorezov 1981, Zhang 1994)
Kazakhstan	(CFIA 2001)
Kazakhstan[2]	(CAB 2003, EPPO 2005a)
Kazakhstan[2] (northeast)	(Konefal and Karnkowski 2003)
Korea	(CFIA 2001)
Korea[1]	(Rozhkov 1970)
Korea[2]	(Zhang 1994, Konefal and Karnkowski 2003)
Korea [2], Democratic Peoples Republic of	(Gninenko and Orlinskii 2002, CAB 2003, EPPO 2005a)
Korea[2], Democratic Peoples Republic of (Ryanggang Province)	(Allard 1998)
Korea[2], North	(Nedorezov 1981)
Korea[2], Republic of	(Gninenko and Orlinskii 2002, CAB 2003, EPPO 2005a)
Mongolia	(Zhang 1994, CFIA 2001)
Mongolia[2]	(Nedorezov 1981, CAB 2003)
Mongolia[2] (northern)	(Gninenko and Orlinskii 2002, Konefal and Karnkowski 2003, EPPO 2005a)
Poland[2]	(Allard 1998)
Russia	(Zhang 1994)
Russia (Far East)	(CFIA 2001)
Russia (Kurile Islands)	(Maeto 1991, CFIA 2001)
Russia (Sakhalin Island)	(Maeto 1991, CFIA 2001)
Russia (Siberia)	(Maeto 1991, CFIA 2001, CAB 2003)
Russia[1] (Angara-Yenisei region)	(Rozhkov 1970)
Russia[1] (Baikal, northern)	(Rozhkov 1970)
Russia[1] (Evenkia)	(Galkin 1993)
Russia[1] (Far East)	(Khrimian et al. 2002)
Russia[1] (Irkutsk Oblast, region)	(Vartanov 2002)
Russia[1] (Krasnoyarsk Kray, territory)	(Klun et al. 2000, Vartanov 2002)
Russia[1] (Kurile Islands)	(Rozhkov 1970)
Russia[1] (near the village of Ozernyy in the Republic of Khakassiya)	(Klun et al. 2000)
Russia[1] (Novosibirsk Region)	(Slepneva et al. 1999)
Russia[1] (Primorskii Krai - Dal'nerechyenskii; Chuguyevskii, Arseniyevskii, and Yakovlevskii districts)	(Yurshenko and Turova 1998)
Russia[1] (Sakha (Yakutiya,Yakuta or Yakutia) Republic)	(Rozhkov 1970)
Russia[1] (Siberia)	(Rozhkov 1970, McBride 2000, Khrimian et al. 2002)
Russia[1] (Siberia, Shira region of the Khakass (Khakassiya) Republic)	(Khrimian et al. 2002)
Russia[1] (Siberia,central)	(Grodnitsky and Raznobarskii 2002)

Locations	References
Russia[1] (Tuva (Tuve) Republic)	(Rozhkov 1970)
Russia[2]	(Zhang 1994, Allard 1998)
Russia[2] (Altai Region (Republic;Territory))	(Gninenko and Orlinskii 2002)
Russia[2] (Altai-Sayan mountain region-Kan-Agul, Kuznetz-Alatau, Sisim-Tuba, West Sayan, Usa)	(Kharuk et al. 1997)
Russia[2] (Amur region)	(Gninenko and Orlinskii 2002)
Russia[2] (Angara-Yenisei region)	(Krasnoshchekov and Vishnyakova 2003)
Russia[2] (Asia, except far north)	(Konefal and Karnkowski 2003, EPPO 2005a)
Russia[2] (Buryat Republic)	(Gninenko and Orlinskii 2002)
Russia[2] (central and northern European Russia)	(Konefal and Karnkowski 2003)
Russia[2] (central)	(CAB 2003)
Russia[2] (Chita Region)	(Gninenko and Orlinskii 2002)
Russia[2] (eastern European Russia)	(EPPO 2005a)
Russia[2] (eastern Sayan-Emel'yanovskii in Krasnoyarsky kray)	(Krasnoshchekov and Vishnyakova 2003)
Russia[2] (Far East)	(CAB 2003)
Russia[2] (Irkutsk Oblast, region)	(Gninenko and Orlinskii 2002)
Russia[2] (Khabarovsk Territory)	(Gninenko and Orlinskii 2002)
Russia[2] (Krasnoyarsk Kray, territory)	(Ryapolov and Ryapolova 1983, Kharuk et al. 1997, Isaev et al. 1999, Gninenko and Orlinskii 2002)
Russia[2] (Kurile Islands)	(Nedorezov 1981)
Russia[2] (lower Angara River basin (region))	(Krasekha et al. 1985, Vetrova et al. 1998)
Russia[2] (mid Siberian plato region-Priangar, Priyenisey, Kan-Birusa)	(Kharuk et al. 1997)
Russia[2] (Moscow region)	(Gninenko and Orlinskii 2002)
Russia[2] (near Moscow)	(CAB 2003, EPPO 2005a)
Russia[2] (Novosibirsk Region)	(Gninenko and Orlinskii 2002)
Russia[2] (Perm and Udmertia)	(CAB 2003, EPPO 2005a)
Russia[2] (region of Niznee Priangar'e between the Yenisey and Angara Rivers (approx. 90° E. Lon.))	(Kharuk et al. 1997, Ranson et al. 2004)
Russia[2] (Republic of Bashkiriya)	(Gninenko and Orlinskii 2002)
Russia[2] (Republic of Marii El)	(Gninenko and Orlinskii 2002)
Russia[2] (Sakha (Yakutiya,Yakuta or Yakutia) Republic)	(Gninenko and Orlinskii 2002, Gninenko and Sidel'nik 2003)
Russia[2] (Sakhalin)	(Nedorezov 1981)
Russia[2] (Siberia)	(CAB 2003, EPPO 2005a)
Russia[2] (Siberia, eastern)	(CAB 2003)
Russia[2] (Siberia, southeastern)	(Gninenko and Orlinskii 2002)
Russia[2] (Siberia, western)	(Nedorezov 1981, CAB 2003, Ranson et al. 2004)
Russia[2] (south of the optimal heat-moisture ratio isoline in the west Siberian lowland territory, Siberian Uvals)	(Kolomiets 1995)
Russia[2] (southern Primorye (Prumor'e)	(Kolomiets 1978, Nedorezov 1981)

Locations	References
Territory)	
Russia[2] (southern Ural Mts. In the Chelyabinsk Region)	(Gninenko and Orlinskii 2002)
Russia[2] (Tomsk Region)	(Gninenko and Orlinskii 2002)
Russia[2] (town of Malmyzh in the Kirov Region)	(Gninenko and Orlinskii 2002)
Russia[2] (Tuva (Tuve) Republic)	(Nakrokhina and Kondakov 1983, Gninenko and Orlinskii 2002)
Russia[2] (Vovozh forest farm in the Republic of Udmurtiya)	(Gninenko and Orlinskii 2002)
Russia[2] (West Siberian plain region, Chulim-Ket)	(Kharuk et al. 1997)

1. Reported geographic distribution of *Dendrolimus superans sibiricus*
2. Reported geographic distribution of *Dendrolimus sibiricus*

Appendix B. Taxonomy and morphology of *Dendrolimus superans.*

There are conflicting opinions among scientists worldwide regarding the recognized name for the Siberian silk moth. *Dendrolimus superans* (=*Odonestis superans*) was described as a new species in 1877 (Butler 1877). Tshetverikov (1908) later described *D. sibiricus* as a new species (translated variations of the author's name reported in literature include, "Chetverikov" and "Tschetverikov"). A subsequent study of the genus *Dendrolimus* by de LaJonquière (1973), placed *D. sibiricus* Tschetverikov in synonomy with *D. superans*: "*D. superans* Butler (=*D. jezoensis* Matsumura =*D. albolineatus* Matsumura =*D. sibiricus* Tschetverikov) forms: *fentoni* Butler, *concolorata* Matsumura, *frequens* Matsumura, *albosignatus* LaJonquière, etc."

Several non-authoritative references consider *D. superans* and *D. sibiricus* two distinct species (Zhang 1994, CAB 2003) and do not acknowledge the genus revision and synonomy by de LaJonquiere (1973). To add to the confusion, the Siberian moth has been referred to as a subspecies of *D. superans*, namely "*D. superans sibiricus*" (see Table 1 and Appendix A, Table A1), though a review of available literature has not identified subsequent formal revisions in nomenclature. In some translated publications, the names have also been used interchangeably (Rozhkov 1970). According to the European and Mediterranean Plant Protection Organization, EPPO (2005a), "Many Russian scientists believe that there exists a species *Dendrolimus superans* (coniferous silk moth) with two subspecies: *Dendrolimus superans sibiricus* Tschetverikov (Siberian silk moth) widely spread in continental Russia and *Dendrolimus superans albolineatus* Matsumura (Sakhalin silk moth) which occurs on Sakhalin and Kunashir islands ... But, according to the main international opinion (CAB), *Dendrolimus superans sibiricus* corresponds to the species *Dendrolimus sibiricus* (Siberian silk moth), and *Dendrolimus superans albolineatus* to the species *Dendrolimus superans*." According to EPPO (EPPO 2005b), the currently accepted name of the Siberian silk moth is "*Dendrolimus sibiricus* Tschetverikov", and its synonyms include, "*Dendrolimus superans sibiricus* Tschetverikov" and "*Dendrolimus laricis* Tschetverikov."

<u>Diagnostic features</u>

For complete accuracy, the following morphological descriptions are quoted from Butler (Butler 1877) and Rozhkov (Rozhkov 1970).

"[*Dendrolimus*] *superans,* n. sp.
Smoky brown, with a white spot at the end of the cell; primaries with an irregularly sinuous disco-submargina1 whitish-bordered dusky stripe, a slender transverse broadly sinuated discal line; male rather paler than the female, the primaries with a large white subcostal spot near the base, an angulated transverse subbasal line, the centre of interno-median area occupied by a broad white nebula: wings below uniform in coloring, with an indication of a diffused darker discal streak across both wings, Expanse, ♂ 3 inches 3 lines, ♀ 4 inches 3 lines" (Butler 1877).

"*Dendrolimus superans sibiricus* has been known since the 1880's as a very serious pest of conifer forests. Areas of forests dried as a result of the damage caused by this species are estimated at millions of hectares" (Rozhkov 1970).

"Adults densely hairy. Wingspan to 70 mm. Fore wings rounded triangular, costal margin convex. Light gray to dark gray, rarely reddish brown. Two distinct median stripes. Discal spot displaced inward from 2nd median stripe. A shade between the 1st median stripe and the outer stripe, which connects the stripes. Hind wings with indistinct bands" (Rozhkov 1970).

"Eggs oblong, oval, 2.2 x 1.9 mm, smooth, bluish green" (Rozhkov 1970).

"Caterpillars to 80 mm long. Pattern formed by accumulation of scales and hairs very variable. Dorsum usually light, silvery, with dark spots on each segment. Tufts of blue hairs behind 1st and 2nd thoracic segments. Head rounded, brown with a speckled pattern, front and adfrontal sclerites darker than head, sutures light" (Rozhkov 1970).

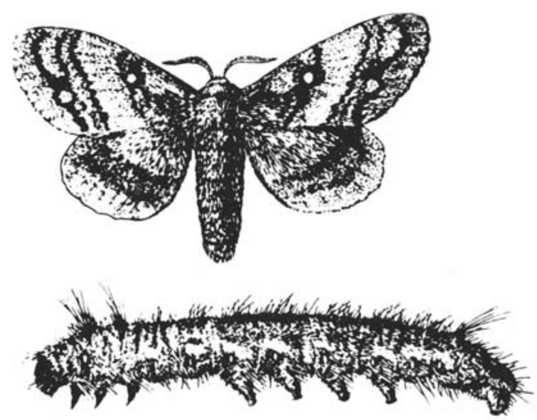

Figure C1. *Dendrolimus sibiricus*. [upper] adult, [lower] caterpillar. [Reproduced from Rozkhov (1966).]

"Pupa 30-36 x 10-11 mm, dark brown to almost black. Head, thorax, and wing sheaths mat, abdomen more shining. Wing sheaths reaching 4^{th} abdominal segment. Cremaster with a small area of coarse hairs. Cocoon gray or brownish, 70 x 12-15 mm, compact, rough, with inclusion of hairs. Cocoons deposited on the underside of branches, near the trunk, sometimes in groups, attached by a large area of the surface" (Rozhkov 1970).

Appendix C. Threatened or endangered plants potentially affected by *Dendrolimus superans*.

Dendrolimus superans has the potential to adversely affect threatened and endangered plant species. However, because *D. superans* is not known to be established in the US and threatened and endangered plant species do not occur outside the US, it is not possible to confirm the host status of these rare plants from the scientific literature. From available host records, *D. superans* is known to feed only on species within Pinaceae (Baranchikov and Kirichenko 2002). From these host records, we infer that threatened or endangered plant species which are closely related to known host plants might also be suitable hosts (Table D1). For our purposes closely related plant species belong to the same genus.

Table C1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Dendrolimus superans*.

	Threatened and/or Endangered Plant		**Protected Status**[1]	
Reported Hosts	**Scientific Name**	**Common Name**	**Federal**	**State**
Abies sibirica, *A. holophylla* *A. nephrolepis* (=*A. gracilis*), *A. sachalinensis*, *Abies* sp.	*A. balsamea*	balsam fir		CT (E)
	A. fraseri	Fraser		TN (T)
Larix kaempferi, *L. sibirica* (=*L. sukaczevii*), *L. gmelinii* (=*L. dahurica*), *Larix* spp.	*L. laricina*	tamarack		IL (T) MD (E)
Picea obovata, *P. ajanensis* (=*P. jezoensis*), *Picea* spp.	*Picea rubens*	red spruce		NJ (E)
Pinus koraiensis, *P. sibirica*, *P. sylvestris*,	*P. banksiana*	jack pine		IL (E) NH (T) VT (T)

Table C1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Dendrolimus superans*.				
Reported Hosts	**Threatened and/or Endangered Plant**		**Protected Status**[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
Pinus thunbergii, *Pinus* sp.	*Pinus echinata*	shortleaf pine		IL (E)
	P. pungens	Table Mountain pine		NJ (E)
	P. resinosa	red pine		CT (E) IL (E) NJ (E)
	P. virginiana	Virginia pine		NY (E)
Tsuga sp.	*Tsuga caroliniana*	Carolina hemlock		TN (T)

1. E= Endangered; T=Threatened

Appendix D. Biology of *Dendrolimus superans*

Population phenology

In Asia, *D. superans* typically completes development in two phases requiring 1-4 years, depending largely on population density, climatic conditions (temperature), host availability, and presence of natural enemies. Cyclic outbreaks have also been observed to coincide with solar activity. Typically the life cycle is 2 years for the majority of the population during outbreaks, and 3 years for the remainder of the population. Life history and stage specific biology has been described by Rozhkov (1970), Tshetverikov (1908), Baranchikov (1997, 2002), the Canadian Food Inspection Agency (CFIA 2001), the European and Mediterranean Plant Protection Organization (EPPO 2005a), Galkin (1993), and Gninenko and Orlinski (2002).

Stage specific biology

Adult

In its native range, *D. superans* adults emerge from mid-June to mid-August during late afternoon and early evening hours and may continue to fly until midnight. Females begin to lay eggs soon after mating. Between 100-150 eggs are laid in a linear fashion on needles and branches on the lower portion of the crown. In outbreak years females may lay an average of 200-300 (maximum of 800) eggs. Egg masses may also occur in unfavorable locations including the forest floor.

Egg

The incubation period is typically 9-22 days.

Larva

Males have 5-9 larval instars and females have 6-10 instars. Larvae may overwinter twice before development is completed. Larvae begin to feed immediately after egg hatch. When feeding, larvae will consume part or all of a needle. Larvae overwinter in forest litter, moving from the host tree to the forest floor once day length is under 12 hours. Larvae typically enter diapause as mid to late instars, and break diapause when the forest litter temperature is 3.5-5°C. Larvae may also enter summer diapause when conditions are unfavorable for development. Larvae feed intensely following diapause, consuming the majority of the food necessary for completing development. Feeding resumes until June or July, followed by pupation.

Pupa

Pupation occurs in cocoons spun with silk, needles and small branches in the crown from mid-June to late July. This stage typically requires about 18-22 days.