United States Department of Agriculture

Animal and Plant Health Inspection Service

Plant Protection and Quarantine

New Pest Response Guidelines

Dendrolimus Pine Moths

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Dendrolimus Pine Moths

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Acknowledgements

Authors

Jesse A. Hardin, Ph.D., USDA-APHIS-PPQ-CPHST-PERAL

Alonso Suazo, Ph.D., USDA-APHIS-PPQ-CPHST-PERAL

Reviewers

Yuri Baranchikov, Professor, Department of Forest Zoology, V.N. Sukachev, Institute of Forest, Siberian Branch of Russian Academy of Sciences, Krasnoyarsk, Russia

Roger Moore, Research Scientist, Centre for Forestry and Climate Change, Forest Research,Northern Research Station, Roslin, Midlothian, UK

Alicja Sierpinska, Zaklad Ochrony Lasu, Instytut Badawczy Lesnictwa, Poland

Technical Assistance and Comments

Karl Suiter, Dave Prokrym, Gary Cave, Esther Spaltenstein, Lynn Garrett, Stefano Costanzo, Katherine Kamminga, Karen Maguylo

Cover Images

Josef Dvořák (www.biolib.cz), and Pest and Diseases Image Library, Bugwood.org

Chapter 1

Introduction

Contents

Introduction

Use *New Pest Response Guidelines: Dendrolimus Pine Moths* when designing a program to detect, monitor, control, contain, or eradicate, an outbreak of any of the following in the United States and collaborating territories:

- *Dendrolimus pini* (L.), pine-tree lappet (PTL)
- *Dendrolimus punctatus* (Walker), the Masson pine caterpillar (MPC)
- *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM)
- *Dendrolimus superans* (Butler), the Sakhalin silk moth (SaSM)

The United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA–APHIS–PPQ) developed the guidelines through discussion, meeting, or agreement with staff members at the USDA-Agricultural Research Service and advisors at universities.

Any new detection may require the establishment of an Incident Command System to facilitate emergency management. This document is meant to provide the necessary information to launch a response to a detection of *Dendrolimus* moths.

If a species of *Dendrolimus* is detected, PPQ personnel will produce a site-specific action plan based on the guidelines. As the program develops and new information becomes available, the guidelines will be updated.

Users

The guidelines is intended as a reference for the following users who have been assigned responsibilities for a plant health emergency for any of the selected Scots pine blister rust:

- PPQ personnel
- Emergency response coordinators
- State agriculture department personnel
- Others concerned with developing local survey or control programs

Contacts

When an emergency pest response program for *Cronartium flaccidum* and *Peridermium pini* has been implemented, the success of the program depends on the cooperation, assistance, and understanding of other involved groups. The appropriate liaisons and information officers should distribute news of the program's progress and developments to interested groups, including the following:

- Academic entities with agricultural interests

- Agricultural interests in other countries
- Commercial interests
- Grower groups such as specific commodity or industry groups
- Land-grant universities and Cooperative Extension Services
- National, State and local news media
- Other Federal, State, county, and municipal agricultural officials
- Public health agencies
- The public
- State and local law enforcement officials
- Tribal governments

Initiating an Emergency Pest Response Program

An emergency pest response program consists of detection and delimitation, and may be followed by programs in regulation, containment, eradication and control. The New Pest Advisory Group (NPAG) will evaluate the pest. After assessing the risk to U.S. plant health, and consulting with experts and regulatory personnel, NPAG will recommend a course of action to PPQ management.

Follow this sequence when initiating an emergency pest response program:

1. A new or reintroduced pest is discovered and reported
2. The pest is examined and pre-identified by regional or area identifier
3. The pest's identity is confirmed by a national taxonomic authority recognized by USDA–APHIS–PPQ-National Identification System
4. Published New Pest Response Guidelines are consulted or a new NPAG is assembled in order to evaluate the pest
5. Depending on the urgency, official notifications are made to the National Plant Board, cooperators, and trading partners
6. A delimiting survey is conducted at the site of detection
7. An Incident Assessment Team may be sent to evaluate the site
8. A recommendation is made, based on the assessment of surveys, other data, and recommendation of the Incident Assessment Team or the NPAG, as follows:
   - **A.** Take no action
   - **B.** Regulate the pest

C. Contain the pest
D. Suppress the pest
E. Eradicate the pest

9. State Departments of Agriculture are consulted
10. If appropriate, a control strategy is selected
11. A PPQ Deputy Administrator authorizes a response
12. A command post is selected and the Incident Command System is implemented
13. State departments of agriculture cooperate with parallel actions using a Unified Command structure
14. Traceback and trace-forward investigations are conducted
15. Field identification procedures are standardized
16. Data reporting is standardized
17. Regulatory actions are taken
18. Environmental Assessments are completed as necessary
19. Treatment is applied for required pest generational time
20. Environmental monitoring is conducted, if appropriate
21. Pest monitoring surveys are conducted to evaluate program success
22. Programs are designed for eradication, containment, or long-term use

Preventing an Infestation

Federal and State regulatory officials must conduct inspections and apply prescribed measures to ensure that pests do not spread within or between properties. Federal and State regulatory officials conducting inspections should follow the sanitation guidelines in the section *Survey Procedures* on page 4-1 before entering and upon leaving each property to prevent contamination.

Scope

The guidelines is divided into the following chapters:

The guidelines also includes appendixes, a references section, a glossary, and an index.

The Introduction contains basic information about the guidelines. This chapter includes the guideline's purpose, scope, users, and application; a list of related documents that provide the authority for the guidelines content; directions about how to use the guidelines; and the conventions (unfamiliar or unique symbols and highlighting) that appear throughout the guidelines.

Authorities

The regulatory authority for taking the actions listed in the guidelines is contained in the following authorities:

- Plant Protection Act of 2000 (Statute 7 USC 7701-7758)
- Executive Order 13175, Consultation and Coordination with Indian and Tribal Governments
- Fish and Wildlife Coordination Act
- National Historic Preservation Act of 1966
- Endangered Species Act
- Endangered and Threatened Plants (50 CFR 17.12)
- National Environmental Policy Act

Program Safety

Safety of the public and program personnel is a priority in pre-program planning and training and throughout program operations. Safety officers and supervisors must enforce on-the-job safety procedures.

Support for Program Decisionmaking

USDA–APHIS–PPQ-Center for Plant Health, Science and Technology (CPHST) provides technical support to emergency pest response program directors about risk assessments, survey methods, control strategies, regulatory treatments, and other aspects of pest response programs. PPQ managers meet with State departments of agriculture in developing guidelines and policies for pest response programs.

How to Use the Guidelines

The guidelines is a portable electronic document that is updated periodically. Download the current version from its source, and then use Adobe Reader® to view it on your computer screen. You can print the guidelines for convenience. However, links and navigational tools are only functional when the document is viewed in Adobe Reader®. Remember that printed copies of the guidelines are obsolete once a new version has been issued.

Conventions

Conventions are established by custom and are widely recognized and accepted. Conventions used in the guidelines are listed in this section.

Advisories

Advisories are used throughout the guidelines to bring important information to your attention. Please carefully review each advisory. The definitions have been updated so that they coincide with the America National Standards Institute (ANSI) and are in the format shown below.

EXAMPLE	Example provides an example of the topic.

Important	Important indicates information that is helpful.

⚠ CAUTION

CAUTION indicates that people could possibly be endangered and slightly hurt.

DANGER

DANGEROUS indicates that people could easily be hurt or killed.

NOTICE

NOTICE indicates a possibly dangerous situation where goods might be damaged.

WARNING

WARNING indicates that people could possibly be hurt or killed.

Boldfacing

Boldfaced type is used to highlight negative or important words. These words are: never, not, do not, other than, prohibited.

Lists

Bulleted lists indicate that there is no order to the information being listed. Numbered lists indicate that information will be used in a particular order.

Disclaimers

All disclaimers are located on the unnumbered page that follows the cover.

Table of Contents

Every chapter has a table of contents that lists the heading titles at the beginning to help facilitate finding information.

Control Data

Information placed at the top and bottom of each page helps users keep track of where they are in the guidelines. At the top of the page is the chapter and first-level heading. At the bottom of the page is the month, year, title, and page number. PPQ–EDP-Emergency Programs is the unit responsible for the content of the guidelines.

Change Bar

A vertical black change bar in the left margin is used to indicate a change in the guidelines. Change bars from the previous update are deleted when the chapter or appendix is revised.

Decision Tables

Decision tables are used throughout the guidelines. The first and middle columns in each table represent conditions, and the last column represents the action to take after all conditions listed for that row are considered. Begin with the column headings and move left-to-right, and if the condition does not apply, then continue one row at a time until you find the condition that does apply.

Table 1-1 How to Use Decision Tables

If you:	And if the condition applies:	Then:
Read this column cell and row first	Continue in this cell	TAKE the action listed in this cell
Find the previous condition did not apply, then read this column cell	Continue in this cell	TAKE the action listed in this cell

Footnotes

Footnotes comment on or cite a reference to text and are referenced by number. The footnotes used in the guidelines include general text footnotes, figure footnotes, and table footnotes. General text footnotes are located at the bottom of the page.

When space allows, figure and table footnotes are located directly below the associated figure or table. However, for multi-page tables or tables that cover the length of a page, footnote numbers and footnote text cannot be listed on the same page. If a table or figure continues beyond one page, the associated footnotes will appear on the page following the end of the figure or table.

Heading Levels

Within each chapter and section there can be four heading levels; each heading is green and is located within the middle and right side of the page. The first-level heading is indicated by a horizontal line across the page, and the heading follows directly below. The second-, third-, and fourth-level headings each have a font size smaller than the preceding heading level. The fourth-level heading runs in with the text that follows.

Hypertext Links

Figures, headings, and tables are cross-referenced in the body of the guidelines and are highlighted in boldface type. These appear in blue hypertext in the online guidelines.

Italics

The following items are italicized throughout the guidelines:

- Cross-references to headings and titles
- Names of publications
- Scientific names

Numbering Scheme

A two-level numbering scheme is used in the guidelines for pages, tables, and figures. The first number represents the chapter. The second number represented the page, table, or figure. This numbering scheme allows for identifying and updating. Dashes are used in page numbering to differentiate page numbers from decimal points.

Transmittal Number

The transmittal number contains the month, year, and a consecutively-issued number (beginning with -01 for the first edition and increasing consecutively for each update to the edition). The transmittal number is only changed when the specific chapter sections, appendixes, or glossary, tables, or index is updated. If no changes are made, then the transmittal number remains the unchanged. The transmittal number only changes for the entire guidelines when a new edition is issued or changes are made to the entire guidelines.

Acknowledgements

Writers, editors, reviewers, creators of cover images, and other contributors to the guidelines, are acknowledged in the acknowledgements section. Names, affiliations, and Web site addresses of the creators of photographic images, illustrations, and diagrams, are acknowledged in the caption accompanying the figure.

How to Cite the Guidelines

Cite the guidelines as follows: U.S. Department of Agriculture, Animal Plant Health Inspection Service, Plant Protection and Quarantine. 2011. *New Pest Response Guidelines: Dendrolimus Pine Moths*. Washington, D.C. http://www.aphis.usda.gov/import_export/plants/manuals/online_manuals.shtml

How to Find More Information

Contact USDA–APHIS–PPQ–EDP-Emergency Management for more information about the guidelines. Refer to *Resources* on page A-1 for contact information.

Chapter 2

Pest Information

Contents

Introduction

Use *Chapter 2 Pest Information* to learn more about the classification, history, host range, and biology of the *Dendrolimus* pine moths:

- Pine-tree lappet, *Dendrolimus pini* (L.)
- Masson pine caterpillar, *Dendrolimus punctatus* (Walker)
- Siberian silk moth, *Dendrolimus sibiricus* Tschetverikov
- Sakhalin silk moth, *Dendrolimus superans* (Butler)

Classification

Use *Table 2-1* on page 2-1 as a guide to the classification of the *Dendrolimus* pine moths and the names used to describe it in the guidelines.

Table 2-1 Classification of *Dendrolimus* spp.

Phylum	Arthropoda
Class	Insecta

Table 2-1 Classification of *Dendrolimus* spp.

Order	Lepidoptera
Suborder	Glossata
Family	Cronartiaceae
Subfamily	Pinarinae
Tribe	Pinarini
Genus	*Dendrolimus*
Full Name and Authority	*Dendrolimus pini (Linneaus), Dendrolimus punctatus (Walker), Dendrolimus sibiricus (Tschetverikov (= Chetverikov)), Dendrolimus superans (Butler)*

Table 2-1 Classification of *Dendrolimus* spp.

Synonyms	*Dendrolimus pini: Bombyx pini* Linneaus; *Dendrolimus segregattis*, Butler; *Gastropacha pini* Linneaus; *Lasiocampa pini* Linneaus; *Phalaena pini* Linneaus (Davis et al., 2008) *Dendrolimus punctatus: Dendrolimus baibarana* Matsumura, *Dendrolimus innotata* Walker, *Dendrolimus kantozana* Matsumura, *Dendrolimus pallidiola* Matsumura, *Dendrolimus punctata*, *Eutricha punctata* Felder, *Metanastria punctata* Walker, *Oeona punctata* Walker (CABI, 2011b) *Dendrolimus sibiricus: Dendrolimus sibiricus* Chetverikov, *Dendrolimus laricis* Tschetverikov, *Dendrolimus superans sibiricus* Chetverikov, (EPPO, 2005; Matsumura, 1926a; Mikkola and Stahls, 2008; Orlinskii, 2000) *Dendrolimus superans: Odonestis superans* Butler, *Dendrolimus jezoensis* Matsumura, *Dendrolimus superans albolineatus* Butler, *Dendrolimus albolineatus* Matsumura (EPPO, 2005 CABI, 2011a; Mikkola and Stahls, 2008). Other synonyms reported by Masumura (1926a) include *Eutricha dolosa* Butler, E. *fentoni* Butler, *E. zonata* Butler, *E. pini* Leech and *Bombyx pini* Sasak
Common Names	*Dendrolimus pini*: PTL, Pine-tree lappet, pine lappet, pine moth, European pine moth, nun moth,(English); lasiocampe du pin (French); lasiocampa del pino (Spanish); kiefernspinner (German); barczatka sosnówka (Polish); tallspinnare (Swedish); furuspinner (Norwegian); bombice del pino (Italian) *Dendrolimus punctatus*: MPC, Masson pine caterpillar, Masson pine moth *Dendrolimus sibiricus*: SSM, Siberian silk moth, Siberian moth, Siberian conifer silk moth, Siberian lasiocampid, larch caterpillar (English translation of Chinese common name), сибирский шелкопряд or Sibirkiy shelkopryad (Russian), Sibirischer Arven-Spinner (German), DENDSI (EPPO code) (CABI, 2011a; EPPO, 2005; Orlinskii, 2000) *Dendrolimus superans*: SaSM, Sakhalin silk moth,White-lined silk moth, Japanese hemlock caterpillar (English translation of Japanese common name), Japanischer Douglasien-Spinner (German), белополосьҐй шелкопряд (Russian), Tuga-kareha (Japanese), Feuille morte de tsuga du Japon (French), Japanischer Douglasien Spinner (German), DENDSU (EPPO code) (CABI, 2011a; EPPO, 2005)

Taxonomic History and Synonyms

The species-level assignments within the genus *Dendrolimus* have been subject to several revisions and some uncertainty about the distinctions between species and subspecies. In particular, two of the species under consideration in these guidelines, SSM and SaSM, are considered to be separate species by many in the international community. However, many Russian scientists condisider these to be a single species with subspecies *Dendrolimus superans sibiricus* Chetverikov and *Dendrolimus superans albolineatus* Butler, respectively (EPPO, 2005), as synonymized by LaJonquiere (1973). To add to this confusion, the author's name for the new species *D. sibiricus* in 1908 has been variously translated as 'Tschetverikov' and 'Chetverikov' (Davis et al., 2005).

Nomenclature rules have also influenced proper taxonomic authority of this group, including cases of gender agreement in Latin. The first description of MPC was given the name *Oneona punctata* (in Walker 1855) but the species was later moved to *Dendrolimus punctata* in 1892. However, the genus name 'Dendrolimus' is a 'masculine' Latin word and by convention the species name should be 'masculine' as well. Since 'punctata' is the 'feminine' Latin form, the correct usage should be 'punctatus' following the revision (CABI, 2011a). The Genus *Dendrolimus* is described from the lectotype *D. pini* (L.), although Linneaus originally named the species as *Phalaena pini* Linneaus.

Ecological Range

Dendrolimus pini

The PTL is Native to Europe and Asia. There is no evidence of PTL presence in Oceania, North, Central and South America and the Caribbean Region. The natural range of PTL follows that of its primary host, the Scots pine (*P. sylvestris*). It covers an area that extends from Western Europe, including the United Kingdom to Middle Asia (Northern China, middle Asian Russia and Kazakhstan). Current distribution of the species *sensu lato* is shown in *Table 2-2* on page 2-5. The ecological range of PTL subspecies is limited to smaller areas in Europe: *D. pini ibericus* is found only in Spain and Portugal, *D. pini calabria* in Italy (Marini, 1986), *D. pini cederensis* in Greece, *D. pini schultzeana* in Spain (Zolotuhin and Van Nieukerken, 2004), *D. pini adriatica* and *D. pini paulae* in Southern Turkey (Omer Kocak and Kemal, 2007) and *D. pini corsaria* in Northern France the(Coulondre, 1983).

Table 2-2 Reported Distribution of *Dendrolimus pini* in Eurasia and Asia[1]

Continent	Country	Reference
Africa	Morocco	Le-Cerf, 1932
Central Asia	China	Han et al., 2004
	Kazakhstan	
	Georgia	
	Asian Russia from Western and Middle Siberia to the Transbaikal region	(Issaev and Shividenko, 2002; Nupponen and Michael, 2002; Savela, 2010)
Europe	Andorra	
	Austria	
	Belarus	
	Belgium	
	Boznia-Herzegovina	
	Bulgaria	
	Croatia	
	Czech Republic	Cila, 2002
	Denmark (including Borholm island)	
	Estonia	
	Finland	
	France	Coulondre, 1983
	Germany	
	Greece	

Table 2-2 Reported Distribution of *Dendrolimus pini* in Eurasia and Asia[1]

Continent	Country	Reference
	Hungary	
	Italy (including Sicily and adjacent islands: Lipari, Ustic, Egadi, Pantelleria and Pelagie Is.)	
	Latvia	
	Liechtenstein	
	Lithuania (Dapkus, 2004)	
	Luxembourg	
	Macedonia	
	The Netherlands	
	Norway (Aarvik and Bakke, 1999)	
	Poland	
	Portugal	
	Romania	
	Russia	
	Slovakia	
	Slovenia	
	Spain (including the Baleeric and Alboran Is.)	
	Sweden (Anonymous, 2009; Kiddie, 2007)	
	Switzerland	
	Turkey (Oner et al., 2006)	
	United Kingdom	
	Ukraine	
	Yugoslavia (including Serbia, Kosovo, Voivodina and Montenegro)	

1 Unless otherwise specified, sources are from Zolotuhin and Van Nieukerken, 2004.

Dendrolimus punctatus

The range of MPC is across southeastern Asia, including eastern China, Taiwan, and Vietnam (Billings, 1991; Chang, 1991; Matsumura, 1926a). The northern limit is approximately 33 degrees latitude (Ya-Jie et al., 2005), with a western limit in China of Sichuan province (CABI, 2011b).

Dendrolimus sibiricus

The SSM is found in Russia, China, Kazakhstan, Mongolia and Korea. It is widely distributed in Russia from the west of the Ural mountains in the European part of Russia to the Primorsky Krai in the Far East region of Russia but not found in the extreme north, the Kurile Islands and Sakalin Island (*Table 2-2* on page 2-5 and *Figure 2-1* on page 2-9). In China it has been reported in the provinces of Jilin, Liaoning, Beijing and Neimenggu (EPPO, 2005; Hou, 1987).

Table 2-3 Reported Distribution of *Dendrolimus sibiricus* in Eurasia and Asia

Country	Region or Province	Locality or Areas	Reference
Russia	Perm Krai	Forest near Cherdyn	Mikkola and Stahls, 2008
	Udmurtia	Near Kilmez	Mikkola and Stahls, 2008
	Chelyabinsk Oblast	Near Miass	Mikkola and Stahls, 2008
	Primorye		Mikkola and Stahls, 2008
	Mari El	Novotalyarsky forest	Gninenko and Kryukov, 2007
	Moscow Oblast	Near Pushkino	Gninenko and Kryukov, 2007
	Novosibirsk (Siberia: West)	Chulim-Ket	Gninenko and Orlinskii, 2002; Kharuk et al., 2004
	Krasnoyarsk krai (Siberia: Mid Plateau)	Priangr'e; Prienisey; Kan-Birusa; Kan-Agul; Kuznetz-Alatau; Sisim-Tuba; West Sayan; Usa	Gninenko and Orlinskii, 2002; Kharuk et al., 2004
	Krasnoyarsk krai	Near Krasnoyarsk, Evenkia	Galkin, 1993; Krasnoshchekov and Bezkorovainaya, 2008; Valendik et al., 2006; Y.N. and Y.P., 1997
	Amur		Gninenko, 2003; Gninenko and Orlinskii, 2002
	Khabarovsk	Bolshe-Mikhailovskoye, Udylskoye and Kisilevskoye forest districts	Gninenko, 2003

Table 2-3 Reported Distribution of *Dendrolimus sibiricus* in Eurasia and Asia

Country	Region or Province	Locality or Areas	Reference
	Yakutia	Khangalassky; Gorny, Namsky, Khangalassky, Gorny, Amginsky forests; Central Yakutia	Averensky et al., 2010; Gninenko and Orlinskii, 2002; Vinokurov and Petrovich, 2010
	Tuva Republic		Gninenko and Orlinskii, 2002
	Buryat Replublic		Gninenko and Orlinskii, 2002
	Irkutsk		Gninenko and Orlinskii, 2002
	Altai		Gninenko and Orlinskii, 2002
	Tomsk province		Gninenko and Orlinskii, 2002
	Bashkiriya Republic		Gninenko and Orlinskii, 2002
Mongolia	Inner Mongolia	Aershan Forest	CABI, 2011a; Fei et al., 2008; Ghent and Onken, 2003
China	Jillin province		CABI, 2011a; Liu and Shih, 1957
	Hebei and Beijing province	Weichang county	Hou, 1987; Kong et al., 2007
	Liaoning province	Pulandian City	Kong et al., 2007; Liu and Shih, 1957
	Neimenggu province		CABI, 2011a
	Heilongjiang	Huanan, Shangzhi, Huachuan, Longjian; Shibazhan, Huma, Xinlin, Songling, Qiqihar, Yichun, Jamusi, Bei'an, Dedu, Dailing	CABI, 2011a; Yu and He, 1987; Yue et al., 1996
Kazakhstan			CABI, 2011a; Orlinskii, 2001
Korea (DPR)			CABI, 2011a
Republic of Korea			CABI, 2011a

Dendrolimus superans

The present worldwide distribution of the SaSM is restricted to Japan (Hokkaido and Northern Honshu) (EPPO, 2005; Fukuyama, 1980; Maeto, 1991) and Russia (Sakalin and Kurile Islands as well as some regions of the Russian far east) (Fukuyama, 1980)(*Figure 2-1* on page 2-9).

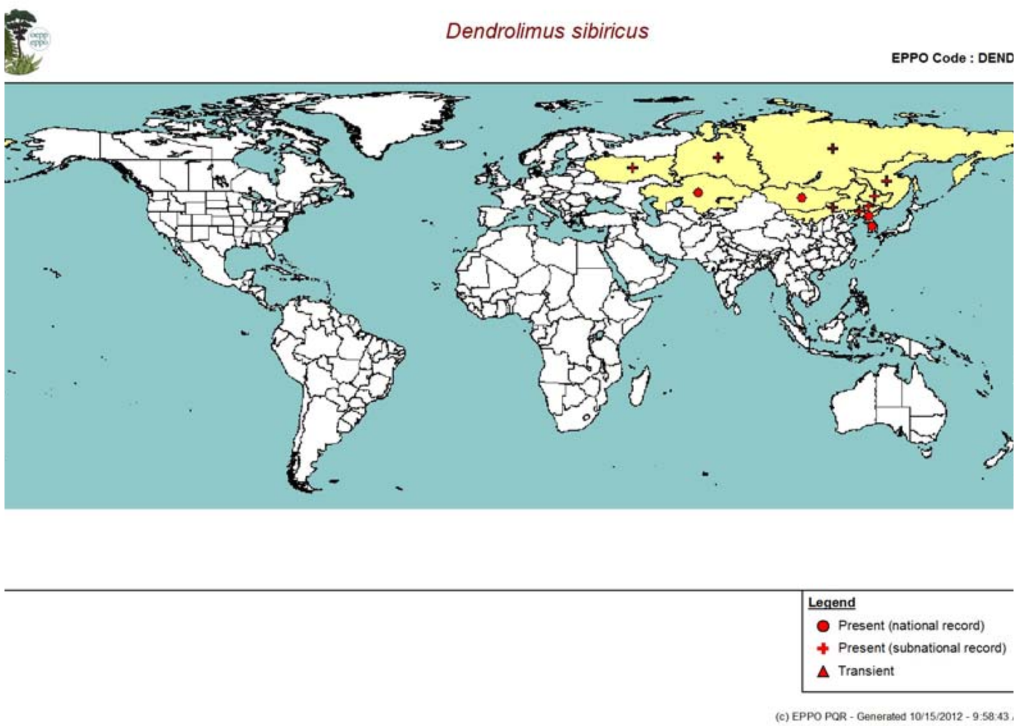

Figure 2-1 World Distribution of A) *Dendrolimus sibiricus* and B) *Dendrolimus superans*. Maps obtained from the European Plant Protection Organization database

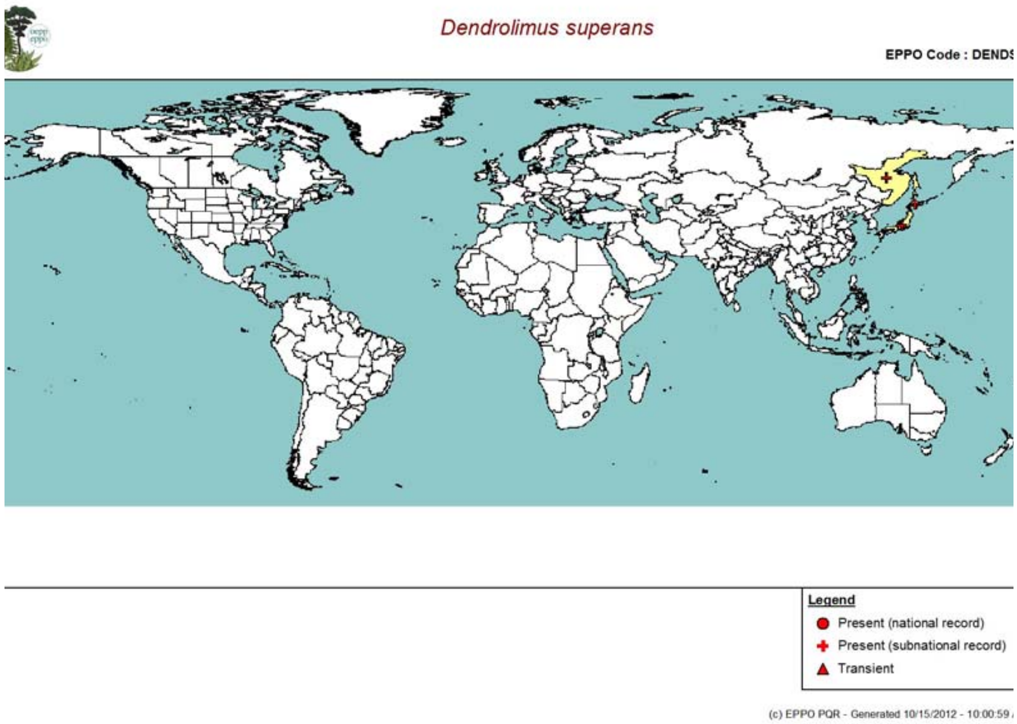

Figure 2-1 World Distribution of A) *Dendrolimus sibiricus* and B) *Dendrolimus superans*. Maps obtained from the European Plant Protection Organization database

Potential Distribution

Dendrolimus pini

Based on climatological suitability and host presence and density in the United States (*Figure 2-2* on page 2-11) the risk of establishment of the PTL is higher in temperate coniferous and mixed (coniferous and deciduous) forests. These forests are distributed throughout the southern Appalachian mountain range, the northeast, midwest (Minnesota, Michigan, Wisconsin, North Dakota), the northwest regions of the United States and Alaska and are primarily found in hardiness zones 4-7. Ecological and environmental conditions are not appropriate for establishment in Puerto Rico, Hawaii or any of the United States territories in the Pacific. The PTL has the highest risk of establishment in temperate forests with high densities of *Pinus* spp.

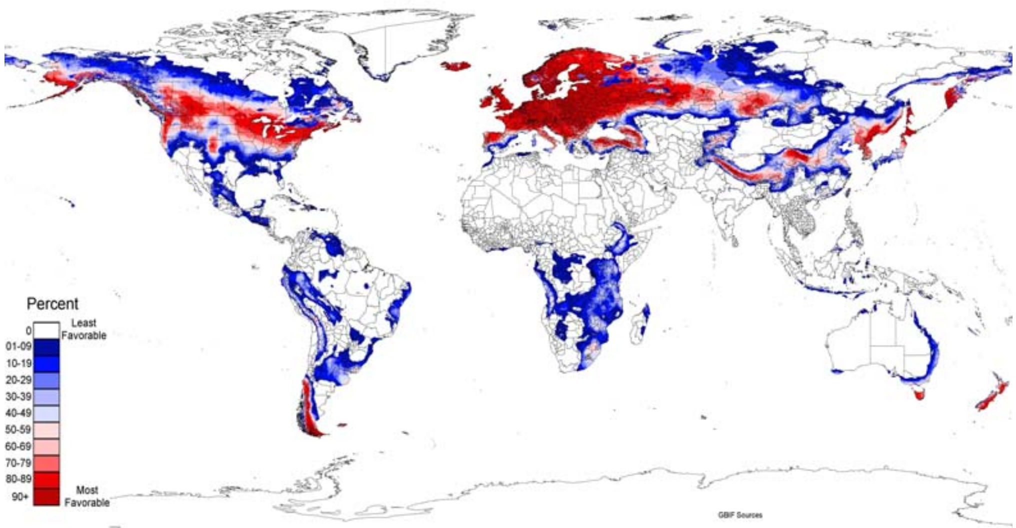

Figure 2-2 NAPPFAST Risk Map for Establishment Potential Based on Climatic Suitability of the PTL in the Conterminous United States (map created by Jessica Engels, Roger Magarey and Dan Borchart; USDA-APHIS-PPQ, Raleigh, NC). The NAPPFAST risk map describes the relative climatic suitability (on a scale of 1-10) for a pest to grow and survive. The maps are based on 10-years of daily data from NAPPFAST. A value of one represents a low likelihood of pest growth and survival, while a 10 indicates high likelihood of pest growth and survival.

Dendrolimus punctatus

Althought the main host for MPC, *P. massoniana*, is not found in the conterminous United States, several alternate hosts are either native or used in plantation foresty. Known alternative hosts (see *Hosts* on page 2-12) such as *P. echinata, P. elliotii*, and *P. taeda* are abundant and widely used timber resources across the Southeastern United States.

Dendrolimus sibiricus and *Dendrolimus superans*

Based on climatological match data obtained from the pest native range (*Figure 2-1* on page 2-9) and the potential host distribution in the United (Alaska included) (*Figure 2-3* on page 2-18), the SSM and the SaSM have the highest potential to establish in coniferous forests of the northern half of the Western United States, Alaska, the upper Northeastern states and in areas of Minnesota, Wisconsin and Michigan. Although several species of Pinaceas are widely distributed in the Southeastern and Midwestern part of the conterminous United State, the likelihood of establishment is low because of undesirable climatological conditions. The relatively warm fall and winter in these areas are unsuitable for the development of the SSM or the SaSM, potentially resulting in the death of hibernating larvae (Baranchikov, Personal communication).

Hosts

The larvae of species in the genus *Dendrolimus* only infest conifer trees. Potential hosts are listed in *Table 2-3* on page 2-7.

Dendrolimus pini

The primary host of PTL is Scots pine (*Pinus sylvestris*). The PTL can also successfully develop on 17 species of pine, as well as Douglas-fir (*Pseudotsuga menziesii* and hemlock (*Tsuga canadensis*). Although most of the species were tested under laboratory conditions, these data clearly show that the PTL host range is possibly broader than is currently known. Most of these species are of economic importance in the United States.

Some of the coniferous tree species in the United States are also reported as primary or secondary host in Europe and Asia (i.e., *Picea sitchensis*, *Pinus contorta*, *P. strobus* and *P. sylvestris*).

Table 2-4 Reported Hosts Species for *Dendrolimus* pine moths

Species	Common Name	*D. pini*	*D. punc-tatu*	*D. sibiri-cus*	*D. super-ans*	U.S.	Reference
Abies alba Miller	European silver fir	Yes		Yes		Yes (NC)	Baldassari, 1996; Kirichenko et al., 2009a; Kirichenko et al., 2008b
Abies concolor (Gord. & Glend.) Lindl.	White fir			Yes		Yes	Kirichenko et al., 2008b
Abies grandis (Dougl. &D.Don) Lindl.	Grand fir	Yes		Yes		Yes	Borowski, 2005; Kirichenko et al., 2008b; Kirichenko et al., 2009b
Abies holophylla Maxim.	Manchurian fir			Yes			Kirichenko et al., 2008b
Abies nephrolepis (Trautv.) Maxim.	Khingan fir			Yes			CABI, 2011a; EPPO, 2005; Kirichenko et al., 2008b
Abies nordmanni-ana (Steven) Loud.	Nordmann fir			Yes			Kirichenko et al., 2009a; Kirichenko et al., 2008b; Mat-sumura, 1926a;
Abies sachalinen-sis Fr. Schmidt.	Sakhalin fir or Todo-fir			Yes	Yes		CABI, 2011a; EPPO, 2005; Kirichenko et al., 2008b
Abies sibirica Ldb.	Siberian fir			Yes			CABI, 2011a; EPPO, 2005; Kha-ruk et al., 2007; Kirichenko et al., 2008b
Pseudotsuga men-ziesii (Mirb.) (= *Pseudotsuga taxi-folia* Britt.)	Douglas-fir	Yes		Yes		Yes	Baldassari, 1996; Borowski, 2005; Fuldner, 2001; Kirichenko et al., 2008a; Kirichenko et al., 2009a; Kirichenko et al., 2009b
Cedrus atlantica glauca Manetti	Blue atlas cedar			Yes			Kirichenko et al., 2008b; Kirichenko et al., 2009b
Cedrus deodara (Roxb.) G.Don	Deodar or Himala-yan cedar	Yes			Yes	Yes	Baldassari, 1996; Kamata, 2002
Cedrus libani Rich.	Lebanon cedar			Yes			Kirichenko et al., 2008b

Table 2-4 Reported Hosts Species for *Dendrolimus* pine moths

Species	Common Name	*D. pini*	*D. punc-tatu*	*D. sibiri-cus*	*D. super-ans*	U.S.	Reference
Larix cajanderis Mayr.				Yes			Averensky et al., 2010; Kirichenko et al., 2008b
Larix dahurica Turcz.				Yes			Matsumura, 1926b
Larix decidua P. Mill	European larch			Yes		Yes	Kirichenko et al., 2009a
Larix eurolepis Henry				Yes			Kirichenko et al., 2008b
Larix gmelinii (Rupr.)	Dahurian larch			Yes	Yes		CABI, 2011a; EPPO, 2005; Kharuk et al., 2007; Kirichenko et al., 2008b;
Larix kaempferi (Lamb.) Carr.	Japanese larch				Yes		Kirichenko et al., 2008b
Larix kamtschatica					Yes	Yes	EPPO, 2005
Larix kurilensis Mayr.				Yes	Yes		Kirichenko et al., 2008b; Meng et al., 2010
Larix olgensis	Olga bay larch			Yes			Liu and Shih, 1957
Larix sibirica Ldb.	Siberian larch			Yes			CABI, 2011a; EPPO, 2005; Kharuk et al., 2007; Kirichenko et al., 2008b
Larix sukaczewii Dyl.	Russian larch			Yes			Kirichenko et al., 2008b
Picea abies L.	Norway spruce	Yes		Yes		Yes	Fuldner, 2001; Kirichenko et al., 2009a; Kirichenko et al., 2008b; Kirichenko et al., 2009b
Picea excelsa L.					Yes		Matsumura, 1926b
Picea glehni Mast.					Yes		Matsumura, 1926b
Picea jezoensis (=P.ajanensis) Fisch.	Yeddo spruce			Yes	Yes		CABI, 2011a; Kirichenko et al., 2008b
Picea obovata Ldb.	Siberian spruce			Yes			CABI, 2011a; EPPO, 2005; Kharuk et al., 2007; Kirichenko et al., 2008b
Picea pumila	Dwarf Norway spruce				Yes		EPPO, 2005

Table 2-4 Reported Hosts Species for *Dendrolimus* pine moths

Species	Common Name	*D. pini*	*D. punctatu*	*D. sibiricus*	*D. superans*	U.S.	Reference
Picea sitchensis Bong.	Sitka spruce	Yes		Yes		Yes	Kirichenko et al., 2008b; Kirichenko et al., 2009b
Pinus caribaea Morelet	Caribbean pine		Yes			HI, PR	Billings, 1991
Pinus cembra L.				Yes			Kirichenko et al., 2008b
Pinus contorta Douglas ex Louden	Lodgepole pine	Yes					Lindelow and Bjorkman, 2001
Pinus echinata Mill.	Shortleaf pine		Yes			Yes	Zhang et al., 2003; Chang and Sun, 1984
Pinus elliotii Engelm.	Swamp pine		Yes			Yes	Ying, 1986a; Chang and Sun, 1984
Pinus halepensis Mill.	Allepo pine	Yes				Yes	Marini, 1986
Pinus kesiya Royle ex Gordon	Khasi pine		Yes				Billings, 1991
Pinus koraiensis Sieb. & Zucc.	Fruit pine, Chinese pinenut			Yes	Yes[1]		CABI, 2011a; EPPO, 2005; Kirichenko et al., 2008b
Pinus luchuensis Mayr	Luchu pine		Yes				
Pinus massoniana Lamb.	Chinese Red Pine		Yes				Billings, 1991; Zhang et al., 2003
Pinus merkussi Jungh	Tenasserim pine		Yes				Billings, 1991
Pinus mugo Turra	Mugo pine	Yes				Yes	Kolk and Starzyk, 1996
Pinus nigra J.F. Arnold (= *Pinus laricio* Poir)	European black pine	Yes		Yes		Yes	Marini, 1986; Kirichenko et al., 2009a
Pinus oocarpa Scheide	Ocote chino		Yes				Billings, 1991
Pinus pinaster Aiton	Maritime pine	Yes				Yes	Marini, 1986
Pinus pinea L.	Italian stone pine	Yes					Marini, 1986
Pinus pumila Rgl.	Dwarf Siberian pine			Yes	Yes[1]		Kirichenko et al., 2008b; Matsumura, 1926b
Pinus sibirica Du Tour	Siberian stone pine	Yes		Yes	Yes		Borowski, 2005; EPPO, 2005; Kharuk et al., 2007

Table 2-4 Reported Hosts Species for *Dendrolimus* pine moths

Species	Common Name	*D. pini*	*D. punc-tatu*	*D. sibiri-cus*	*D. super-ans*	U.S.	Reference
Pinus strobus L.	Eastern white pine	Yes		Yes	Yes[1]	Yes	Borowski, 2005; Kirichenko et al., 2008b; Kirichenko et al., 2009b; Matsumura, 1926b
Pinus sylvestris (L.)	Scots pine	Yes		Yes	Yes[1]	Yes	Fuldner, 2001; Kharuk et al., 2007; Kirichenko et al., 2008b; Kirichenko et al., 2009b; Matsumura, 1926b
Pinus taeda L.	Loblolly pine		Yes	Yes	Yes[1]	Yes	Zhang et al., 2003 Matsumura, 1926b
Pinus thunbergii Franco	Japanese black pine	Yes	Yes	Yes		Yes	Borowski, 2005; Zhang et al., 2003; Kirichenko et al., 2008a
Tsuga canadiensis (L.) Carr.	Eastern Hemlock	Yes		Yes		Yes	Borowski, 2005; Kirichenko et al., 2009b
Tsuga diversifolia (Max) Mast.	Northern Japanese Hemlock			Yes			Kirichenko et al., 2008b
Tsuga sieboldii Carr.	Southern Japanese Hemlock			Yes	Yes		Kirichenko et al., 2008b; Matsumura, 1926a

1 Rarely observed.

Dendrolimus punctatus

The primary host of MPC is Masson pine, *Pinus massoniana* (Zhang et al., 2003). The caterpillars are known to develop on other pines such as *P. elliottii*, *P.taeda* and *P. thunbergii* (Zhang et al., 2003), all of which are common in the Southeastern United States.

Dendrolimus sibiricus

The preferred hosts for the SSM are *Abies sibirica*, *Abies nephrolepsi*, *Pinus sibirica*, *Pinus koraiensis*, *Larix gmelinii*, *Larix sibirica*, *Picea ajanensis* and *Picea obovata* (*Table 2-3* on page 2-7). Because of its current westward migration trend and the potential to establish in Europe (Gninenko and Orlinskii, 2002), the development of the SSM was tested on several species of European Pinaceae not found in the pest native range in Asia (Kirichenko et al., 2006; Kirichenko et al., 2009b). In all species tested, the SSM had the best survival and growth rate when fed Larch (*Larix decidua*). Compared to Larch, survival on *Pinus nigra* and *Pinus silvestris* (Scots pine) was very poor (9 and 30% respectively) and development did not occur in Cupressaceae species (Kirichenko et al., 2009b). The development on Douglas fir (*Pseudotsuga menziesii*) was comparable to that of Larch. Douglas-fir is a species of economic importance in the United States and was intentionally introduced to Europe where it is an economically important non-indigenous forest species (Kirichenko et al., 2006). Other economically important species tested and found in the United States include the Scots pine (*Pinus silvestris*), Eastern white pine (*Pinus strobus*), Grand fir (*Abies grandis*), Sitka spruce (*Picea sitchensis*) and the Eastern Hemlock (*Tsuga canandiensis*) (*Table 2-3* on page 2-7) (Kirichenko et al., 2009b). The potential of the SSM to develop in Pinaceae species not found in their natural ecological range is high and therefore, a large number of species in the United States can potentially be secondary host species (*Table 2-3* on page 2-7).

Dendrolimus superans

The preferred hosts for the SaSM are *Abies sachalinensis*, *Larix kamtschatica*, *L. dahurica*, *Picea jezoensis* (= *P. ajanensis*), *P. glehni*, and *Tsuga sieboldii* (Matsumura, 1926a). It is known to rarely eat the following: *Pinus funebris*, *P. taeda*, *P. koraiensis*, *P. pumila*, *P. strobus*, and *P. sylvestris* (*Table 2-3* on page 2-7). There is little experimental or observational data on the diet breadth of the SaSM outside of the known geographic range for this moth.

Life Cycle

The *Dendrolimus* moths are generally heterovoltine, completing their life cycles within one to five years with some populations consisting of individuals of one or multiple year-cycles living together (Baranchikov and Kirichenko, 2002; Rozhkov, 1963). Factors affecting the duration of a complete life cycle include the population and host density, climatological conditions (temperature, humidity and precipitation) and the density and type of natural enemies (Malyshev, 1987; Malyshev, 1988).

Dendrolimus pini

Adult

The PTL is a nocturnal moth with a life cycle normally completed in two or three years. Moths with a two season life cycle are more common in Central and Southern Europe whereas three season life cycle moths are more common in Russia (Malyshev, 1988). However, Melis, (1940) reported two generations per year in Italy. Unfavorable conditions for the development of the larvae will normally result in a population with a three season life cycle (*Figure 2-3* on page 2-18). High population densities and depletion of food resources will result in 1-year cycle whereas low population densities will result in a 3 season life cycle (Malyshev, 1988). In its native range in Europe and Asia, the moths will normally start their flight activity in June and July (Lesniak, 1976; Varga, 1966).

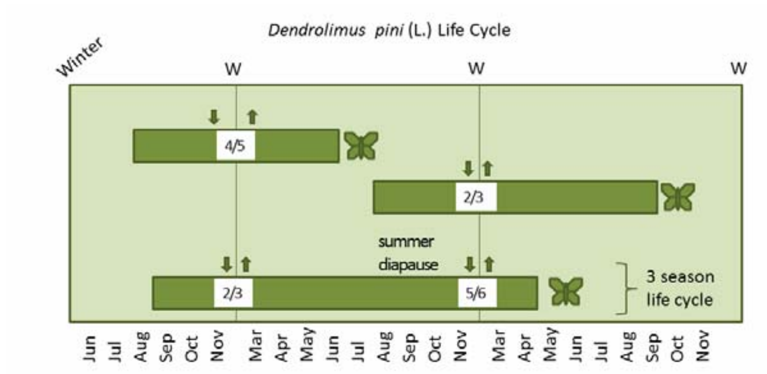

Figure 2-3 Life cycle of *Dendrolimus pini* illustrating the observed presence and timing of different stages throughout the typical calendar year. Vertical lines with a W indicate break in the calendar for winter months when the larvae are not actively feeding. Arrows indicate the migration of larvae down to the forest floor or returning up into the tree canopy. White boxes with numbers indicate the instar number of overwintering larvae. Adult emergence, mating and egg laying is approximated with a butterfly icon on the calendar.

Egg

Mated females will lay a total of 150-250 eggs in their lifespans on the needles, twigs or bark of pine trees in clusters averaging 10-50 eggs/cluster (Ciesla, 2004; Kojima, 1933; Lebedev and Savenkov, 1930; Melis, 1940).

Larva

After 16-25 days, the first instar larvae will emerge and start feeding on the outer edges of young needles, progressively feeding until the needles are completely consumed (Ciesla, 2004). The larvae will molt two or three times during the fall feeding season. At the start of the winter season, the fourth or fifth instar larvae will move down from the trees to the forest undercover where they will burrow beneath the leaves, forest litter or soil and remain dormant during the entire winter season (Heitland, 2002). Larvae will begin diapause after their third instar. Larval diapause is triggered by the photoperiod, usually when the day length is less than 12 hours for an average of 38 days and it is inhibited with longer days, when the day length is more than 17 hours (Geispits et al., 1972). Before diapausing, the larva will gradually decrease its feeding and locomotion activity and excrete the gut content (Geispits et al., 1972; Pszczolkowski and Smagghe, 1999). When the spring starts the following year, and the day length is more than 17 hrs, the larvae will climb back to the tree and resume their feeding activity until ready to pupate. It is during this time that the larvae cause most of the damage to the trees because of their size and the quantity of food consumed during feeding. Spring feeding can be as much as 3 to 5 times more per larva than fall feeding (Ciesla, 2004). Before they pupate, PTL larvae will undergo two to three additional molts in the spring.

Pupa

When ready to pupate, the seventh or eighth instar larvae will crawl several hundred meters in search of a suitable pupation site, normally on the tree crowns, bark and occasionally on the understory vegetation. During pupation the larvae spin spindle-shaped cocoons with silk sometimes covered with pine needles and twigs. Pupation starts in late spring (May-June) and will last between four to five weeks (Melis, 1940).

Dendrolimus punctatus

Adult

In southern portions of the known range, e.g., Vietnam, MPC is reported to have four generations per year, as follows: March to May; June and July; August and September; and overwintering from October to March (Billings, 1991). The number of generations is variable, ranging from one to five per year. In more northen latitudes there are generally fewer generations per year (*Figure 2-4* on page 2-20). Overlapping generations have been observed with insects in several life-stages on the same tree, while coastal climates may allow larvae to remain active throughout the year. Females lay an average of 300-400 eggs.

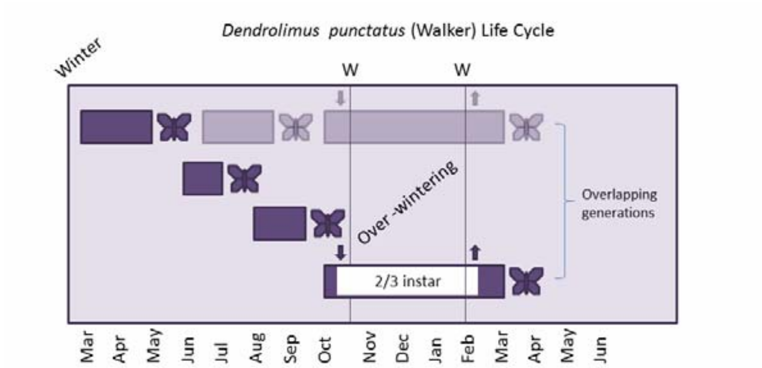

Figure 2-4 Life cycle of *Dendrolimus punctatus* illustrating the observed presence and timing of different stages throughout the typical calendar year. Illustration legend follows Figure 2-3, except overwintering period is indicated completely across the calendar in this figure instead of abbreviated. Lighter lines indicate successive generations, indicating the possibility that overlapping generations might be present in the same population.

Egg

The development time within the eggs stage varies depending on the area and generation. CABI, (2011b) reports:

> [i]n Hunan, the first generation requires 11 days, the second and third generations require 7 days; in Guangxi, the first generation needs 8 days, the second and third generations require 6 days. Newly hatched larvae may feed on the eggshells. Hatching mostly occurs in the early morning (Hou, 1987).

Larva

Hatched larvae can disperse via wind using silk threads, while first and second instar larvae will use the silk threads to suspend in the air when disturbed (CABI, 2011b). Normal development includes six instars. Diapuase can be induced by photoperiod responses during the first 14 days of the larval period, with a critical night length of 10h and 40min at 25-31°C Huang et al., 2005. Nutritional quality has also been implicated as an influence on larval development operating through diapause induction, with increases in the total amount of damage to host pine tree serving to increase the incidence of diapause (Huang et al., 2008). These increases in night length or damage to the plant would have the effect of increasing overall development time in the larval life stage. It has been suggested that serious damage to the host pine trees in the first and second generations of a growing season would tend to decrease the population of the subsequent generations via the diapause mechanisms (Huang et al., 2008).

Pupa

Larvae spin hairy cocoons attached to needles and small branches (CABI, 2011b).

Dendrolimus sibiricus

Adults

In the northernmost latitudes of Russia, adults SSM start emerging from mid to late June and sometimes until the beginning of August (Galkin, 1993). In the southernmost range in China, adults emerge from July to the end of August with peak emergence in mid August (Liu and Shih, 1957). A few hours after emergence, adult moths will fly and mate. Flight is more intense during clear nights and can last up to 4 hours. Flight activity is suppressed during rainy days, during which the moths will remain on the tree crowns hanging from the underside of branches (Galkin, 1993; Liu and Shih, 1957). Galkin (1993) reports that flight duration is shorter in the northernmost limits of the SSM natural range as a possible adaptation of the moths to shorter growing seasons. Mating takes place as soon as 2 to 3 hours after emergence with females normally mating once with a single male (Liu and Shih, 1957). Mated females will start laying fertilized eggs the same night they mate, usually in rows or clusters with up to 200 eggs per cluster or egg mass. A single female can lay from 200-300 eggs with a maximum of 800 eggs (EPPO, 2005).

Larva

After 16 to 21 days, the first instar larvae of the SSM hatch and will remain in groups (Galkin, 1993; Liu and Shih, 1957). The total number of instars in a full life cycle varies from six to eight depending on whether the life cycle is completed in one, two or three years. For a one year life cycle, the larvae will molt three more times to reach the fourth instar. In September, the fifth instar larvae migrate to the forest floor to overwinter underneath the forest litter. Exact determination of overwintering is triggered by a drop in temperatures, an increase in precipitation, changes in the biochemical composition and coloration of larch needles and a shortening of the photoperiods (Galkin, 1993; Geispits, 1965). In spring of the following year, when the soil temperature average 3.5 to 5.0ºC the overwintering larvae break diapause, climb to the tree and resume feeding (FAO, 2007). This is the most destructive stage because of the size of the larvae and its voracious feeding. The larvae will complete seven instars and pupate in June. Before pupation, ~90% of larvae will move to the tree crown and spin a silken cocoon, where they will remain for 18-22 days until they emerge as adults (Galkin, 1993; Liu and Shih, 1957). Three season life cycles are typical for populations in the southern portions of the SSM ecological range. In an expanded three season life cycle, larve in the first to third instar overwinter in the first year. In spring of the following year the larvae will climb back to the tree, molt to fifth instars and overwinter as fifth or sixth instar larvae until they reemerge in spring of the second year, pupate and emerge as adults (*Figure 2-5* on page 2-22).

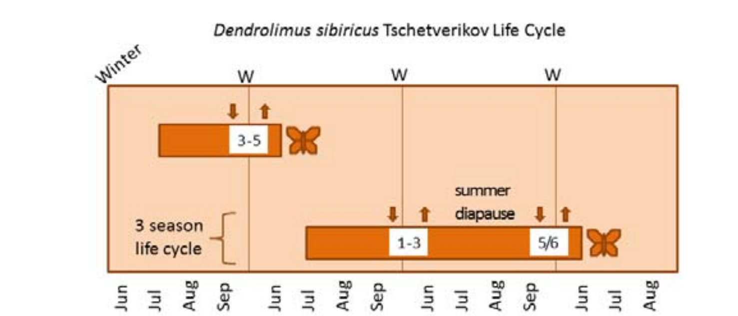

Figure 2-5 Life cycle of *Dendrolimus sibiricus* illustrating the observed presence and timing of different stages throughout the typical calendar year, following conventions used in Fig. 2-3.

Dendrolimus superans

Adult

Emergence of the adults begins in June through July and lasts until August (Fukuyama, 1980). The general patterns of the life cycle are similar to *D. sibiricus* or have not been distinctly defined by research literature. Both two season and three season life cycles are known; *Figure 2-6* on page 2-23 shows general phenology throughout the year which may vary depending on local geographic conditions.

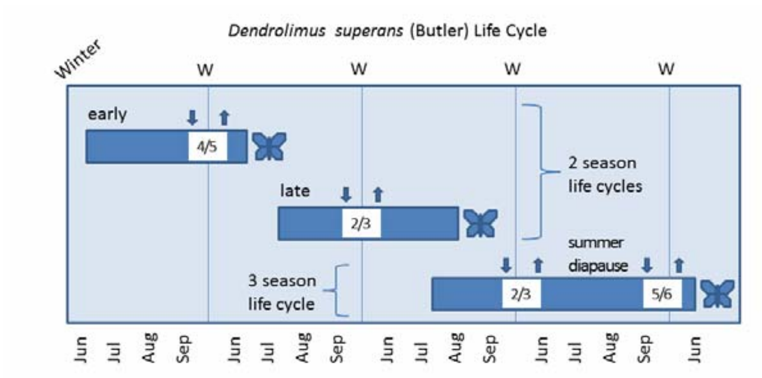

Figure 2-6 Life cycle of *Dendrolimus superans* illustrating the observed presence and timing of different stages throughout the typical calendar year, following conventions used in Fig. 2-3. Moths that overwinter once have a 2 season life cycle, while some moths overwinter twice and diapause in the summer, resulting in a three season life cycle.

Larva

Life cycles can typically require more than one year for development to complete, therefore, generations are often overlapping and hibernation occurs in various instars. Summer diapause is observed to coordinate generations emerging in synchrony, facilitating mating.

Developmental Rates

The duration and development of the life cycle of *Dendrolimus* moths is affected by the interplay of many factors including temperature, humidity, photoperiod, food quality and quantity (type and density of host species), population densities, the abundance and type of natural enemies and certain physiological factors (Galkin, 1993). Specific details relevant to each of the species under consideration are presented below.

Dendrolimus pini

Adult

Developmental time for males and females during the pupal stage does not differ although males will, on average, emerge first, late in the afternoon (around 5:00pm) and females will emerge later during the night (around 8:00pm) (Winokur, 1991). Lifespan of mated females is 7-10 days and that of virgin females is 17-20 days (Lebedev et al., 1929). Mated and virgin females will lay about the same number of eggs during their lifespans, however, eggs laid by virgin females are significantly smaller (Lebedev and Savenkov, 1930). Males live on average 17 days (Lebedev and Savenkov, 1930). Males and females moths will not feed during their lifetime surviving only from the reserves accumulated during larval development (Chainey, 2010).

Food quantity and quality are also important factor that affect the development of the PTL. Smelyanets (1977) showed that oils in Scots pine can be important larval feeding stimulants for example, borneol and camphene; terpenoids like α-pinene, β-pinene and α-terpineol can be feeding deterents and, other terpenoids like limonene, bornilacetate and α-terpineol can be toxic. When found at high concentrations, these toxic compounds will kill the larvae and feeding deterrent terpenoids will reduce larval weigh and increase developmental time (Smelyanets, 1977). Sukovata et al., 2003) found positive correlations between levels of β-pinene and abundance of PTL larvae in Scots pine crowns. The development of larval and pupal stages on different host is variable. Pine-tree lappet larva feeding on Scots pine or spruce (*Picea abies*) develop faster than those feeding on Douglas-fir (*Pseudotsuga menziesii*) (Fuldner, 2001).

Development is also affected by voltinism. Larva developing in 1 or 2 year life cycles will show differences in their pupal developmental time and in the ability of females to fly. Malyshev, (1987) found that the pupal developmental time for 1 year cycle larva was shorter (15 days on average) than those with 2 year cycle (22 days average) and, unlike the 1 year cycle females, females from 2 year cycle moths will normally fly upon emergence (Malyshev, 1988).

Egg

Optimum temperature-humidity combination for PTL egg development was established at 24°C and 80-85% relative humidity, with a range of 14 to 31°C and a relative humidity between 40 to 98% resulting in only 5% egg mortality (Kojima, 1933). Temperatures below 8.5°C and above 33.5°C result in 100% mortality. Eggs developing at optimum temperature but high relative humidity (more than 85%) will normally die because of high levels of potentially pathogenic fungi growing on the surface (Kojima, 1933). However, eggs are more tolerant to incubation at low relative humidity than high humidity conditions. Incubation with relative humidity below 25% will result only in 15% to 18% mortality (Kojima, 1933). At optimal relative humidity, egg development ranged from an average of 10 days at 31.5°C to 48 days at 11.5°C. At the optimum developmental temperature (24°C) and humidity (80-85%) the average developmental time was 11 days. Egg size is another important factor in the development of eggs. Small eggs will normally develop faster than large eggs, possibly related to their nutritional content (Kojima, 1933).

Larva

In first instar larvae, the boundaries of tolerance for temperature and humidity are more restricted than in the egg. A range of 18.0° to 26.5°C and of 55 to 100% relative humidity will result in 5% mortality. However, first instar larvae will tolerate higher and lower temperatures (100% mortality above 37°C and below 7°C) better than the eggs. First instar larvae are also more tolerant to high humidity. Mortality due to pathogenic fungi is observed only when the temperature is above 33°C and 100% relative humidity (Kojima, 1933). The optimum larval developmental temperature and relative conditions was 24°C. For other larval stages, the conditions were comparable to those of first instar larvae (Kojima, 1933).

Pupa

Optimal temperature for pupal development is between 13 and 29.5°C and relative humidity levels between 17% and 100%. Normal pupation is still observed at 7°C. Pupal developmental time ranged from 95 days at 12°C to 14 days at 32°C. Developmental time was 25 days at 24°C (Kojima, 1933; Winokur, 1991).

Dendrolimus punctatus

Limited information is available for the optimum developmental conditions of MPC. The development period for each generation varies according to climate, the number of generations and region.

Adult

Adult lifespan is approximately one week. Reports of adult lifespan vary depending on the region. In Hunan, the average moth life span is 7.5 days in the overwintering generation, 7 days in the first generation, and 8 days in the second generation. In Guangxi, the average life span is 8 days in the overwintering generation and 7 days in other generations (CABI, 2011b).

Egg

Under average temperatures of 28°C, the egg stage is about 8 days; decreases in temperature to average 25°C will increase the egg stage to between 9 and 11 days. At 30°C, egg development is a shorter duration of about 6 days (CABI, 2011b; Hou, 1987; Peng, 1959).

Larva

Larval development time can be greatly extended by diapause but also varies with the number of generations and region. At 28°C, the larvae stage lasts about 32 days, which shortens as the average daily temperature increase to about 26 days at 30°C (Peng, 1959). The diapause period is controlled by day length, but the photoperiod response is also compensated by temperature. The diapause period can last approximately 20 days in Guangdong, 90 days in Hunan, and 120 days in Henan province The reported larvae lifespan is greater than 45 days and less than 65 days, although this range is highly dependent on the region and generation number (CABI, 2011b).

Pupa

In northern parts of its range through China, the pupal stage lasts 21 days in the overwintering generation, 16 days in the first generation, and 13 days in the second generation. In southern China, the pupal stage lasts 16 days in the overwintering generation and from 12 to 17 days depending on which generation is developing (CABI, 2011b).

Dendrolimus sibiricus

In their native range in Russia, optimal development of the moth is found in areas with growing-degree days above 5ºC (GGD5) between 950 and 1350 and annual moisture index values (AMI) between 1.3 and 3.0 and, outbreaks are more prevalent in areas with GGD5 between 1110 and 1250 and, AMI between 2.0 and 2.5 (Baranchikov et al., 2009). In Europe, areas that map with these values are found above latitude 54-56ºN (Baranchikov et al., 2009).

Adult

Newly emerged SSM females will lay eggs for 7-10 days. Average lifespan of mated females is 9 days and that of unmated females is 13 days (Liu and Shih, 1957).

Egg

Development normally takes 13-15 days with a maximum of 20 to 22 days (EPPO, 2005).

Larva

During a typical two-calendar year cycle the number of larval stages for the SSM will vary between five to eight for males and six to nine for females (Baranchikov et al., 1997; EPPO, 2005). First instar larvae molt 9-12 days after emergence. Second instar larvae will develop in 3-4 weeks. The larvae overwinter as second or third instar larvae. In the second year, larvae will either complete development into adults, or will undergo a second winter diapause as fifth or sixth instar larvae on the forest floor. One month after the last winter diapause, the fifth instar larvae molts to sixth instar and complete regular development (EPPO, 2005).

Variations in developmental time for the SSM have been observed in different populations that develop in the same geographic location, some of which complete their life cycle in one, two or three years depending on the local temperature conditions (Galkin, 1993) (*Figure 2-5* on page 2-22). It has been also observed that a population can switch from a one to a two year cycle based on weather conditions (Galkin, 1993). During warm summer and fall seasons, the larvae will grow and molt more readily than those growing in cold summer and fall conditions (Galkin, 1993). Another important factor affecting developmental time is the photoperiod. Long days will accelerate development and days with a LD of 12:12h will stimulate diapause (Geispits, 1965). The combination of long days with warm summer and fall temperatures is ideal for the fast development of both the SSM and the SaSM, a condition that also applies to one of their primary host species, *Larix* spp. (Galkin, 1993). Winter conditions for normal moth development require no autumn thaws, which would be fatal for the hibernating larva (Baranchikov et al., 2009).

One of the most important physiological factors affecting the development of the SSM is the presence and timing of summer diapause (Baranchikov and Kirichenko, 2002). Although it is known that winter diapause is triggered by photoperiod in the fall, the causes that initiate summer diapause in the SSM are not well understood. During summer diapauses, the time spent as a fourth instar larvae increases by 50%, probably as an outcome of a reduction in food consumption and assimilation compared to larvae that do not diapause (Baranchikov and Kirichenko, 2002). Larvae that overwinter as second instars in the first year of their development are not able to fully complete their life cycle in the following year and therefore diapause, or delay growth, in the summer to overwinter as fifth or sixth instars and complete the cycle in the third year, after the second overwintering period. This synchronization is essential to increase the probabilities of mating when the adults emerge (Baranchikov and Kirichenko, 2002).

There is a noted effect of host type on larval development for the SSM. Choice tests show that the SSM prefers and develops faster in *Larix* spp. than on those considered to be poorer quality hosts: *Abies* spp., *Pinus* spp., *Picea* spp. and *Pseudotsuga menziesii* (Kirichenko et al., 2006; Kirichenko et al., 2009b). Larvae fed on *Larix* were on average three times heavier, had a shorter developmental time and the lowest mortality rates compared to those reared on pine species, particularly *P. sylvestris* and *P. nigra* (Kirichenko et al., 2009a; Kirichenko and Baranchikov, 2007). Mortality rates of larvae reared on *P. nigra* were as high as 83% compared to 3.2% in *Larix* spp. (Kirichenko et al., 2008a). It is worth noting that larvae fed on Douglas-Fir, a species of economic importance in Europe and North America, had a development and mortality rate comparable to those reared on *Larix* (Kirichenko et al., 2008a). Compared to other Pinacea, needles from *Larix* have lower essential oil content and higher nitrogen, water and fiber content, a nutritional condition that might favor development and reduce mortality of SSM larvae (Vshivkova, 2004).

Variations in optimal population densities can have an effect in the development, mortality and the physiology of the SSM, and competition for food in populations with high density may extend the developmental time of the larvae and increase the number of instars (Kirichenko and Baranchikov, 2004 Ghent and Onken, 2003). The mortality rate of first instar larvae reared in large numbers (n=20) was reduced 20-fold when compared to individually reared larvae (Kirichenko and Baranchikov, 2004). Population density also affects the duration of development, but studies are mixed on the timing of the effects. Although the duration of development was not affected in first and second instar larvae reared either in groups or isolated, third and fifth instar larvae developed faster and gained more weight when reared in groups (Kirichenko and Baranchikov, 2004). The efficiency of utilization of food (i.e., the measured fraction of assimilated food that turns into tissues) increased in grouped larvae until the fourth instar and dropped in the fifth and sixth instars. Alternatively, in solitary larvae this efficiency was significantly lower in the first to fifth instars relative to the grouped-reared larvae. Finally, development was significantly higher in the isolated sixth instar larvae as compared to grouped larvae (Kirichenko and Baranchikov, 2004). This information suggests that the effect of density correlates with accelerated development of the SSM at early stages of their life cycle (first to third instars) when the larvae are more vulnerable. However, the development of later instar larvae (i.e., fourth to sixth instar) is faster when the larvae grow in isolated conditions, possibly due to reduced competition for food resources (Kirichenko and Baranchikov, 2004).

Pupa

Siberian silk moth pupa develops in one month (EPPO, 2005) but shorter periods of 17-18 days have been reported (Liu and Shih, 1957). The transition of larva to pupa takes on average 3 days (Liu and Shih, 1957). Pupal developmental time in the SaSM is between 19 and 26 days (Inoue and Koizumi, 1958).

Dendrolimus superans

Adult

Newly emerged SSM females will lay eggs for 7-10 days. Average lifespan of mated females is 9 days and that of unmated females is 13 days (Liu and Shih, 1957).

Larva

The SaSM develop in one or two year-cycles with 6-7 larval instars for one-year cycle and 7 to 8 instars for a two-year cycle (Inoue and Koizumi, 1958). Total larval developmental time for a one-year cycle is between 340 to 360 days and 676 to 690 days for a two-year cycle. Larval developmental time for one and two-year cycle is shown in *Table 2-5* on page 2-29.

Table 2-5 Average larval developmental time (in days) for the SaSM in one and two-year life cycles[1]

Instar	1-year cycle	2-year cycle
I	8.0	8.0
II	9.8	8.5
III	18.8	17.5
IV	258.0	269.0
V	21.7	34.0
VI	26.5	27.5
VII		44.5
VIII		280.5

1 Values correspond to the average of both males and females. Data from Inoue and Koizumi, 1958.

Pupa

Siberian silk moth pupa develops in one month (EPPO, 2005) but shorter periods of 17-18 days have been reported (Liu and Shih, 1957). The transition of larva to pupa takes on average 3 days (Liu and Shih, 1957). Pupal developmental time in the SaSM is between 19 and 26 days (Inoue and Koizumi, 1958)

Behavior

Dendrolimus pini

Adult

Virgin females emerge from the cocoons in the evening and produce a female-specific sex pheromone that is used to attract males. The primary pheromone components have been identified as (Z,E)-5,7-dodecadienal (Priesner et al., 1984) and additional components that enhance male searching behavior identified as dodeca-cis-5, trans-7-dien-1-ol and the acetate of dodec-cis-5- or trans 7-en-1-ol (Kovalev et al., 1993). Sexual maturation of females happens within a few minutes of emergence and (Lebedev and Savenkov, 1930). Normally, virgin females do not fly when they are newly emerged and will remain in the same tree until mating, which can happen the same night of emergence or can be delayed for up to eight days (Lebedev and Savenkov, 1930). After mating, females will start laying eggs for an average of 8 days (ranging from 3-18 days) before dying (Kojima, 1933; Lebedev and Savenkov, 1930). During the first two days after mating, a mated female will lay 73% of the total number of eggs after which oviposition will greatly decrease until the female dies (Kojima, 1933). Females will fly soon after mating (Kojima, 1933).

Larva

Pine-tree lappet larvae will consume 95% of their food at dawn and dusk (Malyshev, 1987). At first, feeding will be concentrated in old pine needles of 20 to 30 year old trees and as the old needles are consumed, the larvae will feed more on fresh, new needles (Varga, 1966). Young, first instar larvae will start feeding on the outer edges of needles and, as the larva grows, the entire needles will be consumed. Table 2-6 shows the average daily consumptions of each instar, calculated based on a consumption/defecation value (C/F) of 1.2 for *Dendrolimus pini* L. (Tenow and Larson, 1987) and daily frass production values estimated by Gosswald (1934).

Table 2-6 Daily Consumption (in g) of PTL

Instar[1]	Consumption (g/day)[2]	Frass (g/day) (Gosswald, 1934)
I	0.011	0.009
II	0.033	0.028
III	0.067	0.056
IV	0.202	0.169
V	0.856	0.714
VI	1.436	1.197

Table 2-6 Daily Consumption (in g) of PTL

Instar[1]	Consumption (g/day)[2]	Frass (g/day) (Gosswald, 1934)
VII	2.709	2.258
VIII	3.360	2.800

1 The number of instars varies. Gosswald, 1934 reported VIII larval stages.

2 Consumption calculated as 1.2×F, where F is the value for frass production

Dendrolimus punctatus

Adult

Adults emerge occurs at dusk with mating and oviposition taking place at night (Speight and Wylie, 2001). Female moths use needle volatiles to locate suitable host plants for oviposition (Zhao and Yan, 2003), choosing to lay eggs on the needles of shorter, younger Masson pine (*Pinus massoniana*) in preferences to taller, older trees (Zhang et al., 2003). Generations can overlap on the same tree (Billings, 1991).

Larva

Newly hatched larvae stay in a group on needles near the eggshells. When population numbers are low, larvae prefer older needles (Billings, 1991). If the first- and second-instar larvae are disturbed, they suspend in the air through a silk thread extended from the mouth (CABI, 2011b). They may also roll off the needles. Wind, storm and natural enemies kill a large percentage of the young larvae before entering pupation (CABI, 2011b).

Pupa

Mature larvae spin cocoons for pupation on branches or needles of the host tree, occasionally on nearby vegetation (Speight and Wylie, 2001).

Dendrolimus sibiricus

Adult

Female moths will produce a sex-specific pheromone to attract males and mate one to four days after they emerge (Khrimian et al., 2002; Klun et al., 2000; Liu and Shih, 1957). Mating normally takes place at night between 1am and 3am (Liu and Shih, 1957). Right before mating, both males and females will vibrate their wings. Wing vibrations are more intense in males. Males will immediately approach a female and dance around it while vibrating their wings and mate. During mating, a male and a female moth pair together at their abdomen, aligning their bodies with heads facing in opposite directions. They will remain in this position for an average of 13 hours before they separate. A few hours after they separate, the female starts laying viable, fertilized eggs (Liu and Shih, 1957). If females do not mate during this time, they will start laying unfertilized eggs, however, virgin females that are laying eggs can eventually mate and produce viable, fertilized eggs (Liu and Shih, 1957). Eggs are laid in clusters or in straight lines on the pine needles or branches. A female will normally lay between 165 to 501 eggs during her lifetime, most of them (60%) the first day, right after mating (Liu and Shih, 1957). Oviposition normally takes place at night between 7 and 10pm and last on average 8.1days after which the females die (Liu and Shih, 1957).

Larva

Newly emerged larvae will normally remain grouped during the first instar stage. When disturbed, they will produce a silky thread and drop to the forest floor where they will rapidly move in characteristics side to side twisting movements. This behavior is unique to the first instar larvae. Larvae of other instars will not drop and twist when disturbed, instead, they will curl in a C-like position and move slower than the first instar larva (Liu and Shih, 1957). First instar larvae feeds on the outer surface of pine needles, rarely consuming the entire needle. As the larvae grow, the entire needle will be consumed (Liu and Shih, 1957). When ready to overwinter (normally III or IV instar) the larvae migrates to the forest floor where they will search under the forest litter for a suitable place (normally with 1 to 7 cm of moss or leaves) to overwinter. If there is no forest litter or moss near, the larvae will overwinter in crevices of stones or in larch roots (Galkin, 1993). Overwintering rarely happens in the soil. Larvae will overwinter on average at a 25 cm radius from the tree trunk with a maximum of 82cmts on the east side of the trees (Liu and Shih, 1957). If the affected forested area is in a hill, the majority of overwintering larvae are found at the top of the hill and not the base (78 larvae were found around 17 trees sampled on top of a hill compared to 26 larvae in the same number of trees at the bottom of the hill) (Liu and Shih, 1957). When the temperature is around 10ºC in the spring, the overwintering larvae will break diapause and start migrating from the forest floor to the tree tops.

Dendrolimus superans

Because of taxonomic similarities, most information about behavior of *Dendrolimus superans* is combined with *D. sibiricus* and is not distinguished in the literature. Therefore, consult sections on *D. sibiricus* behavior for what is known about these moths.

Population Dynamics

Localized outbreaks of *Dendrolimus* moths generally follow periodic cycles in timing. Certain conditions have been observed to play an increased role in the outbreaks. Environmental factors of temperature and precipitation are most closely correlated with these outbreaks, but the proximate causes are still not well understood. Details for each species are included below.

Dendrolimus pini

Pine-tree lappet outbreaks are periodical and have been reported in Germany, Poland, Lithuania, Austria, Hungary, Ukraine, Czech Republic, Russia and China (Gedminas, 2003; Han et al., 2004; Kolubajiv, 1950; Komarek and Kolubajiv, 1941; Lesniak, 1976; Malyshev, 1997; Meshkova, 2002; Mozolevskaya et al., 2002b; Sierpinska, 1998; Varga, 1966; Varley, 1949). In Lithuania, outbreaks were first reported in 1993 and in Hungary in 1969 (Gedminas and Ziogas, 2008; Varga, 1966). Data available for outbreaks in Poland since 1791 shows periodic outbreaks lasting from 1 to 11 years (Sierpinska, 1998). In the present century, these outbreaks have been reported more frequently in Poland and Germany. In Poland, the average time between outbreaks was 40 years during the 19 and 20th centuries, compared to 7 year intervals in the present century (Sierpinska, 1998). Climatic and meteorological conditions are important factors determining the extent of a population outbreak (Lesniak, 1976). Temperature, relative humidity, precipitation, and number of days with snow covering the ground are among the most important factors. Regions with the most severe outbreaks are characterized by high mean annual temperature (average of 7.8°C) (Lesniak, 1976). Outbreaks will normally occur when the isotherm line in July is around a minimum value of 18°C and for January, the coldest month, around -2.0°C. Outbreaks are usually weaker when the number of days with temperatures below freezing exceeds 50 (Lesniak, 1976).

Outbreaks are also determined by the amount of precipitation in an area. Low precipitation (less than 350mm during the summer) in the driest, warmest areas is a favorable condition (Lesniak, 1976). The amount of snow cover is a factor that will affect the hibernating larvae. The duration and amount of snow cover can have a direct and indirect impact on the survival of hibernating larvae. The lack of snow cover and therefore, insulation, can result in an increased mortality of overwintering larvae found under a shallow layer of litter on the forest (Lesniak, 1976). Temperatures below -4°C will usually kill the larvae. On the other hand, the long prevalence of a snow cover can indirectly affect the overwintering larvae early in the spring when the snow melts because of the proliferation of pathogenic fungi including *Cordyceps militaris* (L.), *Beaveria* sp. and *Paecilomices farinosus* (Holmskjold) (Lesniak, 1976).

Strong outbreaks are usually observed when the summers are long, typically between 90-100 days. Longer summers will allow the larvae to feed for longer and thus grow bigger, a condition that will help the larvae better survive the winter. Longer winters, however, are decrease survival of the overwintering larvae. Short winters with 70-80 days are considered more favorable conditions for outbreaks (Lesniak, 1976).

A climate indicator known as the hydrothermal coefficient (or Seljaninov's coefficient) (HTC) uses precipitation and temperature values for a specific region at a specific time of the year to describe conditions favorable to outbreaks. The strong correlation between the values of the hydrothermal coefficient and the severity of outbreaks suggests that HTC can be used to predict outbreaks in a region (Meshkova, 2002). The hydrothermal coefficient is calculated as: HTC= (p x 10)/ (t x n) where p is the average monthly precipitation in mm, t the average monthly temperature (in °C) and n the number of days during that month (Lesniak, 1976).

In Poland, weaker outbreaks occur in areas with slightly high humidity and hydrothermal coefficient values between 1.4 and 1.6 and strong outbreaks in areas with the lowest HTC values, below 1.4 (Lesniak, 1976).

Dendrolimus punctatus

As with other *Dendrolimus* spp., the MPC is periodical in outbreaks. The cycles range between 3-5 years. Trees in the 7-15 year age class are the most frequently attacked (Ciesla, 2001); average infestations of 200 larvae per tree can increase up to more than 600 larvae per tree in cases of severe population expansion (Billings, 1991). Overwintering larvae appear to be attracted to each other and assume an aggregated distribution (Liu, 2010), a feature that should be considered when predictions of population dynamics are generated from survey data.

Dendrolimus sibiricus

Outbreaks of SSM are periodical and occur on average every 10-11 years (Baranchikov et al., 1997; Orlinskii, 2000). Outbreaks have been strongly correlated to cycles of solar activity (Galkin, 1975). Climatological factors such as rain and amount of snow during the winter play an important role in regulating the populations of SSM. A shallow snow cover during the winter can cause high mortality on hibernating larvae because of inadequate insulation to the extreme temperatures during the winter.

Elevation, slope steepness and altitude are topographical characteristics that affect the severity of an outbreak. Kharuk (2007) found that the most severe defoliation and tree mortality was observed at an elevation between 200 and 310 meters. Slopes with southwestern exposure receive more solar radiation which creates drier and warmer conditions, favorable for larval development. Maximum damage was observed on slopes between 5° and 20ºC (Kharuk et al., 2007). The highest concentration of SSM larvae is normally found on the hill tops (Liu and Shih, 1957) a place that is more effective for females to disperse their pheromones, attract males, mate and lay their eggs (Li et al., 1987).

The development and intensity of an outbreak is also dependent on the forest species composition and abundance. Outbreaks in Larch forests normally last 2 years until trees are completely defoliated but because of the high resistance of *Larix* trees to both moth species, these outbreaks will not result in high tree mortality and very rarely, affected trees are attacked by secondary pest like insect borers (Averensky et al., 2010; Baranchikov et al., 1997; Rozhkov, 1970). In exceptional cases, when the outbreaks last more than two years, possibly due to extended developmental time of the larvae resulting from insufficient amounts of food and malnutrition, some tree mortality can be observed (Rozhkov, 1970). In contrast to Larch forests, other coniferous forests are more susceptible to outbreaks and tree mortality followed by secondary pests attack and forest fires are more common (Rozhkov, 1970). The severity of the outbreak is also determined by the age of the forest stand. SSM outbreaks are more severe when the forest is composed primarily of trees older than 15 years (Li et al., 1987).

Dendrolimus superans

Outbreaks of SaSM are normally preceded by two to three years of drought with mean summer temperatures above the normal average (Maeto, 1991). In Hokkaido, Japan, major outbreaks of *D. superans* were normally preceded by three years of summer temperatures 1ºC higher than the normal temperatures (Maeto, 1991). Excessive rainfall can cause high mortality of first instar larvae, the most vulnerable of all larval stages (Maeto, 1991).

Generally, SaSM needs more than one year to complete a generation, and spends one or two winters in overwintering as a larva (Fukuyama, 1980). Although the density increases dramatically with outbreak levels, which can be greater than 1,000 individuals per tree (Fukuyama, 1980), population levels are normally do not exceed between 1 and 50 larvae per tree Maeto, 1991). Outbreak years typically follow summers with abnormally high mean temperatures, falling within or just after periods in which 3-year average temperatures of August or September were about 1°C higher than normal (Maeto, 1991).

Dispersal

Adults of all *Dendrolimus* spp. can fly several kilometers, although females with eggs may not fly as far (Ciesla, 2001). Air currents may affect adult flight and early instar larvae are capable of balloon flight using silk threads (Speight and Wylie, 2001).

Damage

The main damage is caused by the larva feeding on the needles of pine tree hosts causing extensive defoliation. Completely defoliated trees will normally die if the outbreaks last a few years. The severity of the damage in a forest is determined by the factors affecting the intensity of an outbreak (see *Population Dynamics* above). When larvae densities reach outbreak levels, complete forest stands can be affected causing tree death in a period of 2 to 3 years and covering millions of ha of forested areas (*Figure 2-7* on page 2-37). Trees that survive a period of outbreak are weak and more vulnerable to the attack of secondary pests including wood borers in the families Cerambycidae and Scolytidae (EPPO, 2005; Orlinskii, 2000).

Figure 2-7 Defoliated larch trees by *Dendrolimus sibiricus* in Mongolia (Vladimir Petko, V.N. Sukachev Institute of Forest SB RAS, Bugwood.org).

Economic Impact

In the United States, the populations of Scots pine and other potential coniferous host species of *Dendrolimus* are probably more vulnerable to attack than those in Europe and Asia because they have not been exposed and have probably not evolved natural plant defense mechanisms to these pests. Scots pine, the PTL primary host, and Douglas-Fir (*Pseudotsuga menziesii*), are two of the most popular species of conifers used for Christmas trees, an industry that in the United States has an estimated value of $506 million USD per year (USDA-NASS, 2009). Christmas tree production is also important in other states like Wisconsin, Pennsylvania, Washington and Michigan. The establishment of any invasive *Dendrolimus* spp.in the United States would therefore represent a high risk to this industry. Other coniferous species in the United States with significant commercial value for the production of timber and pulp that can also be severely affected include ponderosa pine (*P. ponderosa*), lodgepole pine (*P. contorta*), fir (*Abies* spp.), spruce (*Picea* spp.), pinyon pines (several species including *P. cembroides*, *P. orizabensis* and *P. edulis*) and junipers (*Juniperus* spp.) in the west coast and, longleaf (*P. palustris*), shortleaf (*P. echinata*), slash pine (*P. elliottii*) and loblolly pine (*P. taeda*) in the east coast (National Atlas, 2000).

Affected trees are also more vulnerable to the attack of other forest pests. Trees that recover from the extensive defoliation caused by the larval feeding have a reduced growth and weak natural defenses, making them more susceptible to attack by secondary pests like wood borers including *Acanthocinus carinulatus, Ips typographus, I. subelongatus, Melanophila guttulata, Monochamus galloprovincialis, M. urussovi, M. sutor, Phaenops cyanae*, *Scolytus morawitzi, and Xylotrechus altaicus* (Ciesla, 2004; EPPO, 2005; Fei et al., 2008; Ma et al., 1998). Recovery of damaged trees can take several years and depends on the severity of the damage, particularly damage to the crown and weather conditions (Sliwa and Cichowski, 1975). In severely affected areas, the increase in the number of defoliated and dead trees results in higher risks of forest fires (Baranchikov, 1997; Ciesla, 2004; Orlinskii, 2000).

The introduction and establishment of *Dendrolimus* moths in the United States could also have a negative impact on domestic and international trading. Exports of wood and wood products from the United States would have to be subjected to additional quarantine regulations and treated to prevent the spread of *Dendrolimus* moths to other countries where they are absent.

Forests in states and national parks in the western United States are primarily composed of coniferous tree species with pine trees alone covering an estimated 13.8% of the total forest area (CAPS, 2008). High defoliation during outbreaks of *Dendrolimus* spp. can make these forests less attractive, negatively impacting tourism (Davis et al., 2008).

Dendrolimus pini

PTL is a serious pest of coniferous forests in Europe and Asia where it causes extensive defoliation to pine trees during periods of outbreaks. Outbreaks can cover thousands of hectares and last for as long as nine years in areas where Scots pine (*Pinus sylvestris*), the moth's primary host, is the dominant forest species (Malyshev, 1997; Sierpinska, 1998; Varley, 1949). In forests in Poland, where Scots pine covers an estimated 70% of the total forested areas, outbreaks have been reported since the late nineteen century. Between 1946 and 1995 these outbreaks have resulted in extensive aerial treatments of 233,000 ha to control PTL (Sierpinska, 1998). During severe outbreaks, pine trees can be completely defoliated. Trees with more than 90% defoliation will die after the second or third year of the outbreak and those that survive after several years of infestation will show a significant reduction in growth and thus, wood production (Csoka, 1991; Gedminas, 2003; Sliwa and Cichowski, 1975). Sliwa and Cichowski (1975) estimated that defoliated trees that regenerated foliage showed a 60% reduction in height growth, 30% reduction in diameter growth and 30% reduction in wood volume.

Outbreaks have also been reported in Germany and Russia. In Germany, more than 100,000 ha of forest were affected in the period between 1994 to1995. Insecticide applications to control the moth covered an estimated 105,000 ha between 2004 and 2006 (Moeller and Engelmann, 2008). In Russia, the area of pine stands completely killed by PTL between 1990 and 2001 was 116,000 ha (Mozolevskaya et al., 2002b).

Dendrolimus punctatus

MPC is a serious defoliator of pine plantations in Southeast Asia, particularly damaging in southern China and Vietnam where it feeds on *P. massoniana* and *P. merkusii* in silvicultural settings (Ying, 1986b) . Outbreaks can rapidly lead to high deforestation, resulting in more than 50% deforestation of affected areas (Billings, 1991). The severity and impact of infestations can variable depending on the many factors listed in the relevant sections above (including, e.g., environmental factors, generation times, host plant species and density).

Dendrolimus sibiricus

SSM is the most devastating defoliator pest of coniferous forests in Russia, China, Mongolia and Kazakhstan where it feeds primarily on *Pinus sibirica*, *Larix sibirica*, *Abies sibirica*, *Picea obovata, Larix cajanderi* (in Russia and Kazakhstan) and *Larix gmelinii* (in China) (Averensky et al., 2010; CABI, 2011a; EPPO, 2005). Periodical outbreaks results in the death of millions of trees over extensive areas and may last up to 12 years (Averensky et al., 2010). In Russia, trees covering an estimated area of 14.67 million ha were killed by extensive SSM defoliation between 1990 and 2001 with the outbreak of 2000-2001 being one of the most devastating (13.11 million ha). By comparison damages were estimated at 116,000 ha from PTL and 9.76 million ha from *Lymantria dispar*, the Gypsy moth, over the same time period (Mozolevskaya et al., 2002a). In Siberia, ten outbreaks have been recorded since 1873 of which the last five (over the period of 1935 to 1997) have resulted in the defoliation and death of trees in an estimated area of 5.40 million ha (Baranchikov, 1997). In Yakutia, eight outbreaks have been reported from 1948 to 1999 resulting in 870,000 ha of *Larix* forests defoliated (Averensky et al., 2010). During the period of 1980 to 1990 it was estimated that 15 million m^3 of wood were lost in Siberian forests due to SSM damage (Shvidenko et al., 1998). Outbreaks in Mongolia have been equally devastating. In the Khan Khentii and Bogd regions an estimated one million ha of larch and pine forest were severely damaged by SSM (Ghent and Onken, 2003). In Jilin province in China, 13 million trees were lost due to extensive defoliation in 1953 alone (Liu and Shih, 1957).

Affected trees die during extensive periods of outbreaks lasting several years. However, certain species, most notably *Larix cajanderi* can tolerate heavy infestations better than other species (For example pines, fir and spruce) because of their high capacity to regenerate leaves. *Larix cajanderi* can tolerate 50-70% defoliation during two consecutive seasons and trees can fully recover from the damage in a few years thus, facilitating the recovery of the forest and the ecosystem (Averensky et al., 2010).

Dendrolimus superans

The SaSM is one of the most serious defoliators of coniferous forests in Hokkaido (Japan) and the Sakhalin Islands (Russia) with periodical outbreaks occurring on average every 10 years (Fukuyama, 1980). Damage to forests in Hokkaido and the Sakhalin Island is comparable to that of SSM in continental Russia and China with outbreaks reported in 1919 (200,000 ha damaged), 1941, 1952, 1962 (15,356 ha damaged) and 1976 covering thousands of ha of larch-pine forests (EPPO, 2005; Fukuyama, 1980; Maeto, 1991). On Hokkaido Island it reaches outbreaks levels feeding on *Abies sachaliensis* whereas in Honshu Island the outbreaks are restricted to *Picea jezoensis* (Kamata, 2002). Like other *Dendrolimus* spp., trees that survive defoliation by the SaSM are weak and susceptible to attack by wood borers (mostly cerambicids and scolytids) during and after periods of outbreaks (EPPO, 2005).

Environmental Impact

The massive defoliation caused by the *Dendrolimus* moths during an outbreak dramatically changes the ecosystem of a forest. Defoliation allows the entry of more light and precipitation and alters the microclimatic conditions of the forest floor creating growth conditions ideal for other plant and animal species (Gedminas and Ziogas, 2008; Ierusalimov, 1973). Larval feeding on pine needles make nutrients readily available for plants (carbon and nitrogen) through their large production of frass (Mellec and Michalzik, 2008). Extensive defoliation in a forest also increases the risk of forest fires as a result of the accumulation of dry wood from dead trees, which also represents a loss of habitat for many forest living species of plants and animals that rely on the affected tree species for food and shelter (Davis et al., 2008). A more direct environmental impact is the effect of pesticides on non-target organisms and, the accumulation of pesticides residues in the soil and water sources like rivers, streams and lakes (Hilszczanski, 1998; Jakel and Roth, 1998).

There is a direct risk to human health consisting of allergies and dermatitis resulting from exposure to larvae droppings and toxic compounds secreted from the spines and hairs of live and/or dead larvae and cocoons (Diaz, 2005; Moore et al., 2006). Direct contact with hair and spines of live or dead larvae can result in severe dendrolimiasis, a form of dermatitis produced by larvae of the genus *Dendrolimus* and characterized by severe dermatitis, inflammatory arthritis, cartilage inflammation, chronic osteoarthritits and acute scleritis in some cases (Diaz, 2005; Moore et al., 2006). Reports from China strongly correlate the incidence of dendrolimiasis in both male and female patients with outbreaks of *Dendrolimus* species (Diaz, 2005), particularly *D. punctatus* Huang, 1991. Affected patients usually recover after the outbreaks but a small percentage (7%) suffered permanent damage including ankyloses of finger joints or deformed auricles (Diaz, 2005).

Sunlight intensity and therefore, soil temperature increase at the forest floor promoting the growth of plant species commonly found at high densities at the forest edges in unaffected forests. Averensky (2010) summarized this effect between intact and silk moth affected larch forest (*Table 2-7* on page 2-42).

Table 2-7 Change in growth conditions in silk moth affected Larix forests[1]

Larix forest	Light intensity, thousand luxe	Ground thawing depth (cm)	Surface air temperature, ºC	Soil temperature ºC						
				Depth (cm)						
				5	10	20	30	40	50	80
Intact	11.8±8.5	60-80	24.3	13.7	10.2	6.9	4.9	3.9	3	0.6
Silk moth affected	26.8±4.2	110	24.6	16.3	13.1	9.2	7.5	6.4	5.0	0.7

1 From Averensky et al., 2010.

The increase in temperature on the forest floor can also represent a threat to permafrost taiga landscapes as it leads to the development of thermokarst (irregular surfaces that form lakes) as higher soil temperatures thaw the permafrost, thereby increasing the soil water content (Averensky et al., 2010). Methane, a powerful greenhouse gas, stored in the permafrost is released into the atmosphere leading to an increase in greenhouse gases and potentially contributing to global climate change (Anisimov, 2007; Zhuang et al., 2009). The massive amounts of frass produced during an outbreak directly affect soil fertility and increase the levels of microorganisms such as ammonifying phototrophs and microorganisms involved in humus mineralization. Frass also increases the leaching of water soluble carbon (Krasnoshchekov and Bezkorovainaya, 2008; Krasnoshchekov and Vishnyakova, 2003).

There are no known US distributions of hosts for *Dendrolimus* moths listed on the Federally Registered Threatened and Endangered Species lists.

Chapter

3

Identification

Contents

Introduction

Use *Chapter 3 Identification* as a guide to recognizing the following *Dendrolimus* moths:

- Pine-tree lappet, *Dendrolimus pini* (L.)
- Pine caterpillar, *Dendrolimus punctatus* Walker
- Siberian silk moth, *Dendrolimus sibiricus* Tschetverikov
- Sakhalin silk moth, *Dendrolimus superans* (Butler)

Accurate identification of the pest is pivotal to assessing its potential risk, developing a survey strategy, and determining the level and manner of control.

Authorities

Qualified State, County, or cooperating University, personnel may perform preliminary identification and screening of suspect Dendrolimus moths. Before survey and control activities are initiated in the United States, an authority recognized by USDA–APHIS–PPQ-National Identification Services must confirm the identity of such pests. Submit specimens to the USDA-National Identification Services (NIS).

Reporting

Forward reports of positive identifications by national specialists to PPQ-National Identification Service (NIS) in Riverdale, Maryland, according to Agency protocol. NIS will report the identification status of these tentative and confirmed records to PPQ-Emergency and Domestic Programs (EDP). EDP will report the results to all other appropriate parties.

For further information on reporting and submitting samples, refer to *How to Submit Insect Specimens* on page C-1 and *Taxonomic Support for Surveys* on page D-1.

Description

Use the morphological characteristics described in this section to identify *Dendrolimus* moths.

Dendrolimus pini

Adults

Sexual dimorphism in the PTL is well defined. Females are stocky, covered by rusty brown to dark brown hairs in the abdomen and thorax respectively, large with a wing span between 70-90mm. Although individual variation in wing pattern and coloration is large, the female moth hind wings are normally dark brown with no marks. The fore wings have three distinctive transverse black lines (antemedian, postmedian and subterminal) that define very distinctive transverse rusty-brown and grey areas (Mikkola and Stahls, 2008). The outermost line, (subterminal) with a clear and very characteristic serrated and undulated pattern borders the rusty-brown area formed between the subterminal and postmedian lines, overlying an ash-grey background. In the female, these areas are generally paler than males (Mikkola and Stahls, 2008). The coloration of the band defined by the subterminal and postmedial lines is very similar to that of the hind wing. Wing color outside these brown areas is normally grey or brownish-grey. A white and/or black shaded spot is located on the antemedial line about one third from the frontal wing edge. These markings are very useful to distinguish the pine-tree lappet from other similar species (for example SSM and SaSM) (Mikkola and Stahls, 2008). The female head has a pair of big globular eyes, small ocelli and short, pectinate to nearly filiform antennae composed of 53-60 segments (Melis, 1940; Mikkola and Stahls, 2008) (*Figure 3-1* on page 3-3).

Males are smaller and more slender than females with a wing span from 50-70mm. Bipectinated antennae with 58-64 segments are designed to detect the pheromone produced by the females (Melis, 1940).

Figure 3-1 Images of male (left) and female (right) *Dendrolimus pini* (L), pine-tree lappet (PTL) adults. © Serge Peslier

Eggs

Newly laid eggs are green or blue and will turn grey after a few days (*Figure 3-2* on page 3-3). Eggs are 2.6-2.8 mm long and 2 mm wide and chorion with grainy texture (Melis, 1940), laid in clusters of 50 to 100 on the tips of branches.

Figure 3-2 Pine-tree lappet eggs on pine needle. © Jeroen Voogd (www.ukmoths.org.uk)

Figure 3-3 Pine-tree lappet eggs with larvae on Scot's pine (*Pinus sylvestris*) needles (Hannes Lemme, Bugwood.org)

Larvae

Seven to eight instars are observed during larval development. The last larval instar is about 80 mm long and covered with soft red or gray hair. The thorax is distinctively marked with a white band bordered by two blue bands and the abdomen has characteristic V marks on the last two segments (Melis, 1940) (*Figure 3-4* on page 3-5). Head capsule measurements and larval weighs for each instar are given in *Table 3-1* on page 3-4 (Pszczolkowski and Smagghe, 1999).

Table 3-1 Head capsule width and body weighs of the PTL larval instars (means ± S.E)

Instar	Head capsule width (mm)	Body weight (mg)
I	1.27 ± 0.02	12.5 ± 0.1
II	1.63 ± 0.02	30.6 ±2.2
III	1.84 ± 0.04	54.1 ± 3.7
IV	2.22 ± 0.09	76.8 ± 4.2
V	2.94 ± 0.15	197.1 ± 18.5
VI	3.33 ± 0.16	583.8 ± 27.4
VII	5.01 ± 0.22	2542.3 ± 74.8

Figure 3-4 Pine-tree lappet larva. (Jeroen Voogd, www.ukmoths.org.uk).

Pupae

Larvae create spindle-shaped cocoons for pupation with variable coloration ranging from grey to brown. Cocoon length is between 45 to 54 mm and 15 to 20 mm in diameter. Pupae are dark brown or reddish brown and measure on average 30 to 35 mm long and 9 to12 mm wide (Melis, 1940). Cocoons with female pupae are longer and wider than cocoons containing male pupae, averaging 54 ± 4.2mm in length and 19 ± 2.5mm in width compared to 47 ± 2.6mm by 16 ± 2.0mm in males (Winokur, 1991). Blue thoracic hairs of the last instar larvae can be usually seen on the exterior surface of the newly spun cocoons (Melis, 1940).

Figure 3-5 Pine-tree lappet cocoon containing pupa (Hannes Lemme, Bugwood.org)

Dendrolimus punctatus

Adults

Adult wingspan is approximately 50 to 80 mm, the females typically larger than the males (Ciesla, 2001). Males measure in length from 21 to 32 mm, with a wingspan of 38-62 mm. Female length is between 20 to 32 mm long, with a wingspan of 42 to 80 mm (CABI, 2011b). In coloration, the forewings are medium, dull grey or brown (Ciesla, 2001 with 5 lines including an antemedial, medial, double postmedial, and a submarginal line interrupted into dark brown series of spots (Matsumura, 1926a). Additional descriptions of these wing markings from CABI include:

> The front wings are longer and narrower than the hind wings. From the base to the tip of the front wing, there are a series of transverse marks or dark stripes. The outer stripe is dentate. The middle stripe is weakly double-lined. The white spot at the end of median cell of the front wing is small. There is a dark spot in the middle of the hind wing. The hairs on the wing border are greyish-white or greyish-brown. There is a dark curved band underneath the wings. (CABI, 2011b)

The antennae are pectinate (CABI, 2011b) with short branches (Matsumura, 1926a).

The genitalia are important in distinguishing the MPC from other *Dendrolimus* spp., especially in the male where the minor harpe is entirely wanting (Matsumura, 1926a) or slender and very sharp, rarely more than half the length of the major harpe (CABI, 2011b). A single row of small teeth runs along the outer edge of the chitinized portion of the clasper (CABI, 2011b; Matsumura, 1926a).

Eggs

The eggs are found in rows on pine needles (*Figure 3-6* on page 3-7), oval in shape and range in color from rose to light brown (Ciesla, 2001) or pale-greenish, purplish or pale-yellow (CABI, 2011b).

Figure 3-6 Eggs of *Dendrolimus punctatus*, Masson pine moth, on pine needles (William M. Ciesla, Forest Health Management International, Bugwood.org)

Larvae

Larvae grow through 6 instars and are between 5.5 and 7 cm in length when mature (Billings, 1991; Ciesla, 2001). The larvae have alternating patterns of light grey and dark bands with orange markings in the black bands and longitudinal bands along the body from head to the last abdominal segment (CABI, 2011b). White setae are found on the lateral sides of the body. There are urticating hairs on the thorax and abdomen of the larvae that can cause skin and eye irritation as well as other health difficulties (Ciesla, 2001; Huang, 1991). Two color forms of the larvae have been noted: brownish-red and black (CABI, 2011b). For a more detailed description, Matsumura (Matsumura, 1926a) provide the following:

> Head reddish brown and concolorously pubescent; epicranial suture paler, along which on each side is a fuscous stripe, scattering some fuscous spots on the lateral borders, and some of them altogether building 2 or 3 longitudinal stripes; clypeus black; labrum very shallowly emarginated in the middle; antennae brown. Cervical shield reddish brown, with 2 conspicuous dark stripes, which end anteriorly in some long black hair. Body testaceous brown, marmorated with black; the hair clusters in the second and third segments purplish dark brown, the interspace of which is pubescent *with* long white hair; from the 3rd to the last segments covered

dorsally with narrow silvery white scales, those of the 3rd, 4th, 5th. and 6th with some golden yellow scales; the 6th, 7th, 8th, and 8th segments on the subdorsal regions with each pair of long stalked, spaturated, bluish black scale clusters; each segment dorsally black, but as it covered with white scales, its ground colour being not conspicuous; subdorsal stripes paler; stigmatical line broad, black, interrupted at the junctures; some long white hair on the lateral protuberances above the legs. Thoracic legs black, each at the apex yellowish brown; abdominal legs brown, in the middle with a wedge-shaped black spot, which is lined 011 both sides with pale yellow; ventral spot-series fuscous (Matsumura, 1926a).

Figure 3-7 Masson pine caterpillar, *Dendrolimus punctatus* (William M. Ciesla, Forest Health Management International, Bugwood.org).

Pupae

Male pupae are 19 to 26 mm long, while females are larger at 26 to 33 mm in length (CABI, 2011b). Pupation occurs in hairy cocoons, attached to needles and small branches (Billings, 1991). In other respects, the pupae are not well described in the literature and would not be diagnostic to identify this species.

Figure 3-8 Cocoons containing pupae of Masson pine caterpillar found on the tips of pine branches (William M. Ciesla, Forest Health Management International, Bugwood.org).

Dendrolimus sibiricus

Adults

The SSM is a relatively large moth with a wingspan measuring between 40 and 60mm in males and 60 to 80mm in females. Females are larger than males with a body length averaging 39mm compared to 31mm in males (EPPO, 2005; Mikkola and Stahls, 2008). The hind wing has no markings and is normally light brown to reddish-brown. The front wings have 3 distinctive black transverse lines and a distinctive white spot within or along the antemedial line (from the thorax outward these lines are named antemedial, postmedial and subterminal) (*Figure 3-9* on page 3-10). There exists extensive color variation in the adults, associated with geographic origin. The most common are the dark grayish form found mostly on the western part of Russia. The unicolorous brown forms are generally found in Eastern Siberian and the Russian Far East; the melanic forms are mainly found in the Buryatiya and the Altai region in Russia (Mikkola and Stahls, 2008).

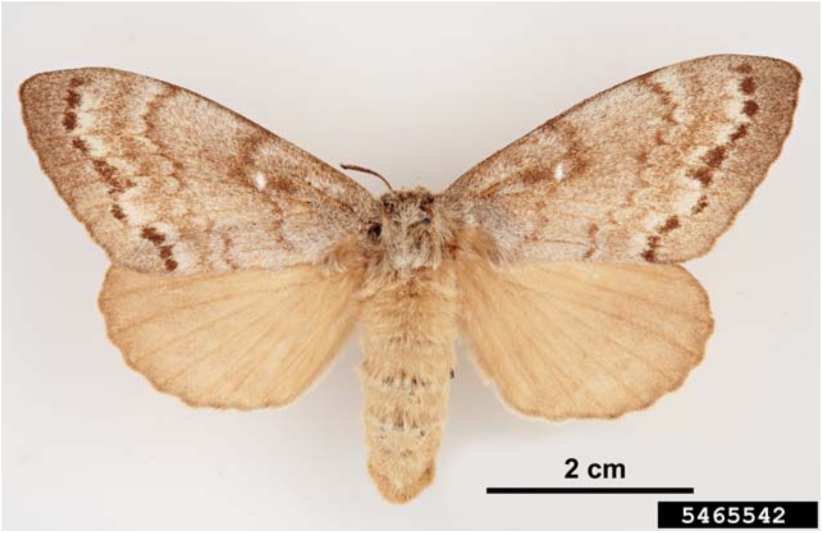

Figure 3-9 Adult Siberian silk moth, *Dendrolimus sibiricus*, photographs showing dorsal view of female (top) and male (bottom)(Pest and Diseases Image Library, Bugwood.org).

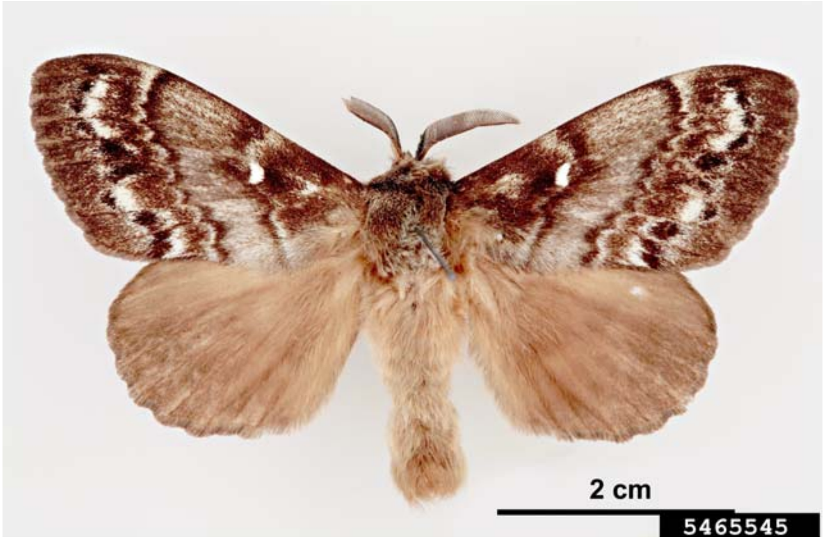

Figure 3-9 Adult Siberian silk moth, *Dendrolimus sibiricus*, photographs showing dorsal view of female (top) and male (bottom)(Pest and Diseases Image Library, Bugwood.org).

Eggs

The eggs of SSM appear oblong and oval, measuring 2.2 X 1.9 mm, and having a light green coloration when first laid turning to a much darker coloration when mature (EPPO, 2005; Rozhkov, 1970). Eggs are laid in clusters on the surface of leaves or branches (*Figure 3-10* on page 3-11). The chorion turns transparent two days before the larvae hatch (Liu and Shih, 1957).

Figure 3-10 Siberian silk moth eggs in clusters (John H. Ghent, USDA Forest Service, Bugwood.org).

Larvae

Final instar larvae of the SSM are on average smaller (50-80mm) than SaSM larvae (60-82mm) (EPPO, 2005; Rozhkov, 1970). For both species, the larvae are hairy, with distinctive blue bands of hairs behind the 1st and 2nd thoracic segment (*Figure 3-11* on page 3-12). A description of the SSM larvae according to Matsumura, 1926b follows:

> Larva dark brown; head reddish brown, opaque, at the occiput with two obsolete short fuscous stripes; clypeus in the middle with a fuscous spot; labrum shining, in the middle shallowly incised. Abdomen yellow, with numerous minute fuscous spots, shield plate of the first segment reddish brown, on its sides marmorated with red, 2^{nd} and 3^{rd} segment dorsally covered with silvery scales, 4^{th} to 12^{th} segments each dorsally with 2 large silvery scaly spots and a diamond marking, the latter being larger at 6^{th} to 8^{th} segment. Stigma yellowish, with black periphery. Thoracic legs except the bases black, abdominal legs yellowish, each on the outer side with a broad fuscous stripe, that of the spurial leg with 2 whitish stripes in it. Venter with a series of fuscous spots, which becoming smaller towards both ends (Matsumura, 1926b).

Figure 3-11 Siberian silk moth larva (Yuri Baranchikov, Institute of Forest SB RASC, Bugwood.org).

Pupae

The pupae of SSM are dark brown to almost black, between 33 and 39mm in length and 10 to 11mm in width for females and between 28 and 34mm in males (EPPO, 2005). Wing sheaths reach to the 4th abdominal segment of the pupae. The cocoon is gray or brownish, measuring 70mm in length and 12 and 15mm in width, appearing compact in shape, with a rough surface (*Figure 3-12* on page 3-13). Blue thoracic hairs from the larva are sometime visible on the cocoon (Rozhkov, 1970). An estimated 90% of the last instar larvae pupate underneath branches on the tree crown, with a small percentage (8.3%) on the tree trunk and very rarely (1%) in other places (Liu and Shih, 1957; Rozhkov, 1970). On average, the last instar larvae pupate in 3 days (Liu and Shih, 1957).

Figure 3-12 Siberian silk moth cocoons on Siberian larch, *Larix sibirica* (John H. Ghent, USDA Forest Service, Bugwood.org).

Dendrolimus superans

Adults

The SaSM is on average larger than the SSM. The wingspan in males ranges between 70 and 75mm and from 80 to 110mm in females (De Lajonquiere, 1973; Matsumura, 1926a). Within the species, the females' bodies are larger, ranging from 28 to 45mm in length compared to between 24 to 37mm for males (Hou, 1987). Adult moths vary in coloration from reddish-yellow to reddish-brown. The characteristic markings of paired transverse lines on the forewings are always present, but can range from well-marked to almost nonexistent. A white spot on the center of the forewing is also variable in size and distinction, in similarity with the SSM. Several major color polymorphisms have been described by De Lajonquiere (1973).

Eggs

Egg of the SaSM are similar in appearances to other *Dendrolimus* moths, oblong or oval shaped, dark green in coloration when mature and laid on needles or small branches in clusters.

Larvae

Larvae of the SaSM are larger, on average, compared to the similarly appearing SSM. The vertex (top of the head) of the larvae has a longitudinal, yellowish-brown stripe (EPPO, 2005 paired on each side black stripe (Matsumura, 1926a). The body is greyish-brown, with marmorated, fuscous (reddish-brown) and yellow markings (Matsumura, 1926a and long hairs; the 2nd and 3rd segments crossed with blue-black stripes and silvery scales, and each segment with a horseshoe-like or hexagonal darker marking (EPPO, 2005). Prior to entering pupation, the larvae reach lengths of 60 to 82mm (EPPO, 2005; Rozhkov, 1970).

Pupae

The pupae are not distinguished from *Dendrolimus sibiricus* in the literature, appearance is the same.

Similar Species

In the United States the PTL can be easily confused with a number of Lasiocampidae and Lymantriidae moths, for example, the gypsy moth (*Lymantria dispar*), the Eastern tent caterpillar (*Malacosoma americanum*, Fabricius), Western tent caterpillar (*M. californicum* (Packard)), Pacific tent caterpillar (*M. constrictum* (H. Edwards)), Southwestern tent caterpillar (*M. incurvum* (H. Edwards)), White satin moth (*Leucoma salisis* L.) and the Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough). In addition to morphological differences, these moth species show clear ecological differences. None of them, with the exception of the Douglas fir Tussock moth, feeds on conifers and except for the Douglas-fir tussock moth, they all lack the white spot on the front wing that is characteristic of several species of *Dendrolimus*. None of the larvae of these species have the distinctive white band between two dark blue or black bands on the thorax and the V shaped marks on the dorsal part of the last abdominal sections (*Figure 3-13* on page 3-16).

The Douglas-fir tussock moth (*O. pseudotsugata* McDunnough) can be distinguished because the adults are much smaller than the adult PTL (30 mm) and darker. Two white spots on the forewings can clearly confuse this moth with the PTL moth, however, the white spots are positioned at the distal edges and not the proximal or basal portion of the front wing (*Figure 3-13* on page 3-16). The spots in *Dendrolimus* moths are located closer to the moth body. The larva of the Douglas-fir tussock moth have two long, dark tufts resembling horns on the terminal dorsal side of the abdomen. Tufts are absent in the PTL larva (*Figure 3-14* on page 3-17).

Figure 3-13 Adults of the Douglas-fir Tussock moth, *Orgyia pseudotsugata* (Sources: Ladd Livingston, Idaho Department of Lands, Bugwood.org(top) and Jerald E. Dewey, USDA Forest Service, Bugwood.org).

Figure 3-14 Larva of the Douglas-fir Tussock moth, *Orgyia pseudotsugata* (Source: Ladd Livingston, Idaho Department of Lands, Bugwood.org).

Dendrolimus Species

Male genitalia are the most important morphological character used to distinguish between the PTL and SSM. Detailed description was presented by Mikkola and Stahls (2008) including keys for the identification of Palearctic species of the genus *Dendrolimus*. For proper identification, the scales and the 8th ventral sclerite of the male abdomen are removed to expose the genitalia. In the Siberian silk moth, five appendages are clearly visible, one large birdbill process (dagger-like structure), two erected appendages termed valve and two additional appendages located to the side of the birdbill process named harpe extend to about two third the length of the process (Baranchikov et al., 2007; Mikkola and Stahls, 2008)(*Figure 3-15 on page -18*). In the pine-tree lappet, the harpe is considerably reduced to about one third the length of the birdbill process, or is lacking, giving the impression that only three appendages are visible (Mikkola and Stahls, 2008)(*Figure 3-15* on page 3-18).

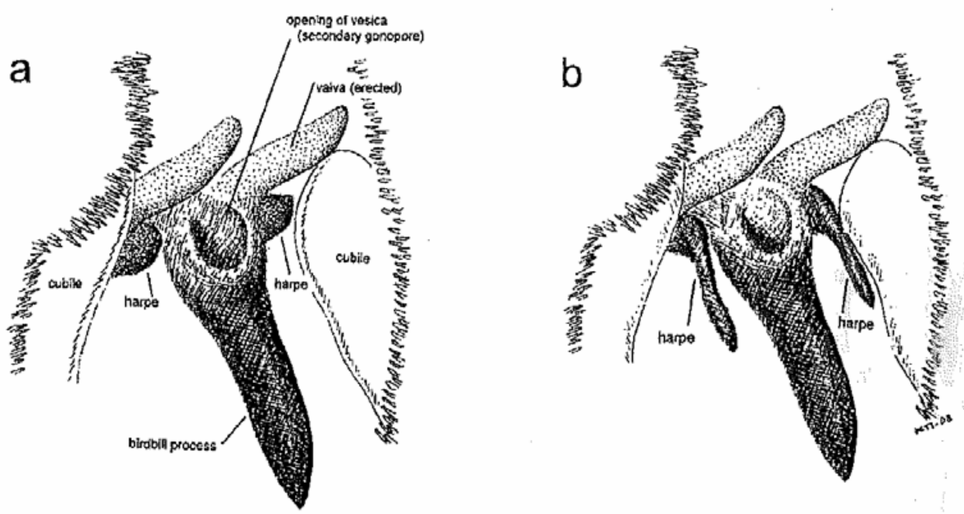

Figure 3-15 Morphological structures of the genitalia of (a) *Dendrolimus pini* and (b) *D. sibiricus* (Mikkola and Ståhls 2008).

Molecular Identification

Molecular identification of *Dendrolimus* species, including PTL, has utilized the polymorphisms found at the sequences from the mitochondrial Cytochrome Oxidase I gene (COI) and the nuclear Internal Transcribed Spacer gene region (ITS2) (Mikkola and Stahls, 2008) as well as microsatellite markers (Moore, 2010). Detailed protocols for the analysis and primer sequences used to amplify the COI and the ITS2 DNA fragments can be found in Mikkola and Stahl (2008).

Molecular tools have been used to characterize populations, to identify new species and to clarify taxonomic ambiguities between species (*D. superans* and *D. sibiricus,* previously believed to be the same species, have been clearly separated as two distinctive species (Mikkola and Stahls, 2008)) and, more recently, to elucidate the origin of introductions of PTL in Scotland (Moore, 2010).

Chapter 4

Survey Procedures

Contents

Introduction

Use *Chapter 4 Survey Procedures* as a guide when conducting a survey for *Dendrolimus* moths, *Dendrolimus pini* (L), pine-tree lappet (PTL); *Dendrolimus punctatus* Walker, Masson Pine caterpillar (MPC); *Dendrolimus sibiricus* Tschetverikov, Siberian silk moth (SSM); and *Dendrolimus superans* (Butler), Sakhalin silk moth (SaSM). For some sections of this chapter, *Dendrolimus* species have been combined where relevant information or recommendations support similar survey methodology.

Survey Types

Plant regulatory officials will conduct detection, delimiting, and monitoring surveys for *Dendrolimus* moths. Conduct detection surveys to ascertain the presence or absence of moths in an area where they are not known to occur. After a new U.S. detection, or when detection in a new area is confirmed, conduct a delimiting survey to define the extent of an infestation. Conduct a monitoring survey to determine the success of control or mitigation activities conducted against a pest.

Preparation, Sanitization, and Clean-Up

This section provides information that will help personnel prepare to conduct a survey; procedures to follow during a survey; and instructions for proper cleaning and sanitizing of supplies and equipment after the survey is finished.

Conduct surveys at the proper time. The schedule should be on a regular time interval that coincides with weather and temperature conditions most suitable for *Dendrolimus*. Surveys of adult moths should be conducted during the time of flight activity and oviposition; for active larva during periods of feeding and periods of movement between the forest canopy and ground litter; and for inactive, overwintering larvae during periods of diapauses. For appropriate timing, consider the stages present and climate conditions in *Life Cycle* on page 2-17.

Once an appropriate survey type and timing has been determined, undertake proper precautions for the specific sites, including the following:

1. Obtain permission from the landowner before entering a property.
2. Determine if quarantines for other pests are in effect for the area being surveyed. Comply with any and all quarantine requirements.
3. When visiting the field, nurseries, or landscape planting to conduct surveys or to take samples, all participants must take strict measures to prevent contamination by *Dendrolimus* moths or other pests between properties during inspections.

   Before entering a new property, make certain that clothing and footwear are clean and free of pests and soil to avoid moving soil-borne pests and arthropods from one property to another. Wash hands. Change clothes if clothing is covered with bugs.
4. Gather together all supplies.

5. Clearly mark the areas sampled whether it is an area on the ground where soil samples were taken or a tree. Mark the sampled location with flagging whenever possible, and draw a map of the immediate area and indicate reference points so that the areas can be found in the future if necessary. Do not rely totally on the flagging or other markers to re-locate a site as they may be removed by other parties or degraded over time. Record the GPS coordinates for each infested host plant location so that the area or plant may be re-sampled if necessary.

Survey task forces should consist of an experienced survey specialist or entomologist familiar with *Dendrolimus* moths and the symptoms of infestation.

Detection Survey

Use a detection survey to determine whether a pest is present in a defined area where it is not known to occur. The detection survey can be broad in scope, as when assessing the presence of the pest over large areas or it may be restricted to determining if a specific pest is present in a focused area (i.e., a greenhouse).

Statistically, a detection survey is not a valid tool to claim that a pest does not exist in an area, even if results are negative. Negative results can be used to provide clues about the mode of dispersal, temporal occurrence, or industry practices. Negative results are also important when compared with results from sites that are topographically, spatially, or geographically similar.

Procedure

Use the following tools singly or in any combination to detect *Dendrolimus* moths:

1. Focus on high risk areas where moths are more likely to be found. See ***Targeted Survey*** on page 4-5 for detailed information.
2. Establish regular sites to inspect along your normal surveying route. See ***Sentinel Site Survey*** on page 4-5 for detailed information.
3. Check plants for pest presence and damage. See ***Visual Inspection of Plants*** on page 4-5 for detailed information

Delimiting Survey after Initial U.S. Detection

Use a delimiting survey to determine the type and extent of control measures to apply. If *Dendrolimus* moths are detected in the United States, delimiting surveys will be needed to determine the distribution of the pest. In large areas, locating the source of an infestation could be difficult.

Procedure

Use the procedure in *Detection Survey* on page 4-3 as a guide. Once *Dendrolimus* moths are detected additional surveys should continue in nearby areas in order to determine the full extent of the infestation. Inspections should encompass continually larger areas, particularly where hosts are known to occur. Surveys should be most intensive around the known positive detections and any discovered through traceback and trace-forward investigations, if possible.

Traceback and Trace-Forward Investigations

Traceback and trace-forward investigations help surveyors to set priorities for delimiting survey activities after an initial detection. Use traceback investigations to determine the source of an infestation. Use trace-forward investigations to determine the potential dissemination of the pest, through means of natural and artificial spread (commercial or private distribution of infested plant material). Once a positive detection is confirmed, conduct investigations in order to determine the extent of the infestation or suspect areas in which to conduct further investigations.

If this pest is found attacking nursery stock, surveyors should compile a list of facilities associated with infested nursery stock. The lists will be distributed by the State to the field offices, and are **not** to be shared with individuals outside USDA–APHIS–PPQ and State regulatory cooperators. Grower names and field locations on the lists are strictly confidential, and any distribution of lists beyond appropriate regulatory agency contacts is prohibited.

Each State is only authorized to see locations within their State and sharing of confidential business information may be restricted between State and Federal entities. Check the privacy laws with the State Plant Health Director for the State.

When notifying growers on the list, be sure to identify yourself as a USDA or State regulatory official conducting an investigation of facilities that may have received material infested with *Dendrolimus*. Speak to the growers or farm managers and obtain proper permission before entering private property. If any sales or distribution has occurred from an infested nursery during the previous six months, surveyors should check nursery records to obtain names and addresses for all sales or distribution sites.

If *Dendrolimus* moths are detected in the United States, a Technical Working Group will be assembled to provide guidance on using monitoring surveys to measure the effectiveness of applied treatments on the pest population.

Monitoring Survey

Dendrolimus punctatus

Examples of permanent forecasting stations were reported to have been established in Vietnam for the purposes of monitoring the MPC. For an area of 500 hectares, a line of four survey plots consisting of 100m² each were used to monitor and predict pending outbreaks (Billings, 1991). Infested sample trees were monitored for population density with 1m² excrement traps, over a 10d period (Billings, 1991). Threshold numbers vary with tree species and insect life-stages.

Targeted Survey

Conduct targeted surveys in areas where introduction of *Dendrolimus* moths may be considered more likely.

Sentinel Site Survey

Sentinel sites are locations that are regularly inspected along the surveyors' normal route. The sites are selected based on their ease of access and the large number of coniferous trees known as primary or potentially secondary hosts.

Once the sentinel site is established the surveyor should re-inspect the site on a regular basis (monthly or bi-monthly) as permitted by the person's regular survey schedule. Any larva, adult, pupa or egg should be processed as described. GIS can be used to map the sentinel site locations to help visualize an even coverage, particularly in high risk areas

Visual Inspection of Plants

This section contains instructions for inspecting trees, the forest undercover and soil for infestation by the *Dendrolimus* moths.

Low level infestations are difficult to detect. Symptoms characteristic of moth damage have to be surveyed from the ground with the naked eye and/or binoculars. It may be necessary to remove branches from the upper canopy to assess infestation or collect samples (*Figure 4-1* on page 4-6). Symptoms of caterpillar presence include:

- Defoliation or needle discoloration in the tree top.

- Caterpillar frass droppings on the forest floor below the tree canopy. This can be collected in nylon nets (300 µm) set up around the perimeter of a tree (le-Mellec and Michalzik, 2008).
- Fragments of pine tree needles that fall to the forest ground as a result of feeding.

Figure 4-1 Trimming branches from Khasia pine, *Pinus kesiya*, to examine Masson Pine Caterpillar infestation levels (William M. Ciesla, Forest Health Management International, Bugwood.org).

What To Look For

Refer to the specific seasons below for details on what to monitor and look for during relevant phases of the *Dendrolimus* moth life cycle. Because local climate conditions may alter the calendar months corresponding to the stages of the life cycle of *Dendrolimus* moths, the following seasonally specific recommendations will provide guidance on appropriate search techniques.

Early spring and late fall: This is the most effective time of the year to look for migrating larva. At the end of the overwintering period and early in the spring, the larva starts moving up to the tree canopy. Larva ready to overwinter will start moving down from the tree canopy to the forest undercover or soil late in the fall before the winter starts. Migrating larvae can be monitored by putting glue bands around trees during this time period (*Figure 4-2* on page 4-8 to *Figure 4-3* on page 4-9). Normally, these larvae are of the IV to VI instars and because of their size, they should be relatively easy to see.

Summer: Preferred time to monitor adult populations using pheromone or light traps. Adult moths are more active at night and are difficult to spot during the day because they camouflage with the bark of pine trees and remain inactive. During the day, look for adult moths on the bark of trees and the presence of egg clusters on branches and needles. The larvae are actively feeding during this period particularly during dusk and dawn and therefore, monitoring for defoliation and larvae presence is recommended.

Late spring and early summer: Late instar larvae pupate at the end of the spring. Cocoons are visible during this time and can be spotted with binoculars or with the naked eye on tip of branches, logs or on the tree canopy. Look for presence of cocoons.

Winter: Larvae overwinter in the leaf litter during the winter. Look for overwintering larvae by sampling between the forest litter and soil and in a 2 m perimeter around the trees. As much as 85% of larvae have been found overwintering inside one-third radius of the tree canopy projection on the ground (Sliwa, 1992) (*Figure 4-4* on page 4-9 to *Figure 4-5* on page 4-10).

Figure 4-2 Surveying for migrating caterpillars using glue bands. Bands with glue are placed at eye level (1.5 to 2 m) around the tree and used to trap migrating caterpillars (between March and April and between November and December) and, to a lesser extent, adult moths flying. © Crown Copyright 2010. Photo courtesy of Forest Research, Scotland, UK/ Roger Moore.

Figure 4-3 Forest stand with glue bands attached to trees for surveying migrating caterpillars. © Crown Copyright 2010. Photo courtesy of Forest Research, Scotland, UK/ Roger Moore.

Figure 4-4 Soil sampling to survey overwintering larva. Sampling is done by collecting soil and forest litter 1-2 m from the tree and visually searching for overwintering larva. © Crown Copyright 2010. Photo courtesy of Forest Research, Scotland UK / Roger Moore.

Figure 4-5 Overwintering larva in forest litter. Larva can be found individually or in groups (Hannes Lemme, Bugwood.org).

Pheromone Traps and Chemical Lures

Dendrolimus pini and *Dendrolimus sibiricus*

Pheromone traps with chemical lures are the preferred method to monitor adult populations. Population surveys for adult males should be done during the season of flight activity, normally between mid-summer months between June and August using pheromone traps or light traps. Pheromone traps and chemical lures to monitor adult male populations of *Dendrolimus* moths are commercially available. Delta, tetra, bucket, funnel and Variotrap traps which were designed to monitor lepidopteran populations are the most commonly used and are fitted with a lure containing the synthetic pheromone blend produced by the female moth. The pheromone components included in the lure are (Z,E)-5,7-Dodecadienal (also Z5,E7-12:Ald) and (Z,E)-5,7-Dodecadien-1-ol (also Z5,E7-12:OH), typically in a 1:1 blend providing the highest capture rates (Kovalev et al., 1993, Alekseev et al., 2000, Klun et al., 2000; Kong et al., 2001, Khrimian et al., 2002, Kong et al., 2007, Baranchikov et al., 2007, Ostrauskas and Ivinskis, 2010). The chemical lures are placed on a rubber septum and hung inside the trap. A killing agent should be placed in the bottom of any traps to limit escape of insects, DDVP is recommended (Jackson, 2011b).

Dendrolimus punctatus

Trapping studies using pheromones have been effective for monitoring populations of SaSM (Zhang et al., 2003). The components of pheromone lures have included (Z, E)-5,7-Dodecadien-1-ol (Z5,E7-12:OH) as well as (Z,E)-5,7-Dodecadienyl acetate (also Z5,E7-12:Ac), and (Z,E)-5,7-Dodecadienyl propionate (also Z5,Z7-12-propionate) for trapping studies (Liénard et al., 2010; Zhang et al., 2003; Zhao et al., 1993). Methods would be similar to PTL and SSM, however updated trap types and methodology can be found by consulting Cooperative Agricultural Pest Survey (CAPS) recommendations (Jackson, 2011a).

Dendrolimus superans

Attractants for SaSM are not available at the time of writing of this document. Consult experts at the National Agricultural Pest Information System (NAPIS) or Cooperative Agricultural Pest Survey (CAPS) for updated information on pheromone traps or chemical lures.

Procedure

Traps are hung from the branches of trees with a wire placing them at eye level (Fig. 4-6), between 1.5 and 2.0 m height and separated to a minimum of 100m between traps. Because the *Dendrolimus* moths are relatively large, consideration should be taken in using a trap size suitable for this species normally, including those commercially available for large lepidopterans. Modifications to milk carton traps (Fig. 4-7) have been approved for CAPS surveys (Jackson, 2011b). Altenkirch (1996) successfully used Variotraps with pheromone lures to monitor PTL populations.

Figure 4-6 An example of placement for monitoring of Dendrolimus moths (William M. Ciesla, Forest Health Management International, Bugwood.org).

Figure 4-7 A milk carton trap for gypsy moth can be modified for use in trapping Dendrolimus moths (Daniel Herms, The Ohio State University, Bugwood.org).

Light Traps

Light traps are commercially available and are the most effective method to monitor adult populations but are more expensive and time-consuming to monitor. Light traps were instrumental in detecting the first pine-tree lappets in the Southern coast of England and the English Channel islands in 2005 (Anonymous, 2009) and have been effectively used by amateur entomologists to report new sightings of adult pine-tree lappet in the United Kingdom (Gould et al., 2009). Light traps are more effective when used during the late afternoon hours (right after sunset) until midnight when adult moths are more actively flying. Males fly earlier than mated females. Light traps are not specific to *Dendrolimus* moths and may attract many different Lepidoptera, therefore, specimens should be preserved and identified properly by a qualified taxonomist.

Preparing Samples

Preserve unknown Lepidoptera in 70-95% percent alcohol and send for identification and preservation.

Shipping Samples

Call the laboratory prior to shipping the samples via overnight delivery service. Instructions and contact information are located in *How to Submit Insect Specimens* on page F-1 and *Taxonomic Support for Surveys* on page G-1.

Collecting and Handling Samples and Specimens

Adults—Moths captured alive adults should be transferred to a killing jar with ethyl acetate (killing agent). Adults will be quickly stunned but will be killed slowly. The body will remain limp (unless they are left in the killing jar overnight) in case spreading or removal of genitalia is needed (USDA, 1986). Alternatively, adults can be collected and placed in 95 percent alcohol. Collecting adults and storing them in dry ice will keep them in good shape in case further taxonomic studies are planned.

Larvae and Pupae—For museum quality specimens, larvae and pupae extracted from plant material should be placed in a vial with ethanol at 70 to 80 percent and 5 percent glacial acetic acid. This combination of chemicals (referred to as acetic alcohol) aids in ethanol penetration and keeps specimen tissues relaxed (USDA, 1986). For surveys, glacial acetic acid is not necessary and 70 to 80 percent ethanol alone is all that is needed.

Immature Stages in Plant Material—Place suspect material in a plastic bag and store in a cooler, but not frozen. A photograph should be taken in the field to document the plant materials original state.

Data Collection

Recording negative results in surveys is just as important as positive detections since it helps define an area of infestation. A system of data collection should include an efficient tracking system for suspect samples such that their status is known at various stages and laboratories in the confirmation process. If available, use pre-programmed hand-held units with GPS capability.

Data collected during surveys should include the following:

- Date of survey
- Collector’s name and affiliation
- Full name of business, institution, or agency
- Full mailing address including country

- Type of property (commercial nursery, hotel, natural field, residence)
- GPS coordinates of the host plant and property
- Host species and cultivar
- General conditions or any other relevant information
- Positive or negative results from specimen collection
- Whenever possible, record wind direction
- Time of capture (day or night)

Cooperation with Other Surveys

Other surveyors regularly sent to the field should be trained to recognize infestations of *Dendrolimus* moths.

Chapter 5

Regulatory Procedures

Contents

Introduction

Use *Chapter 5 Regulatory Procedures* as a guide to the procedures that must be followed by regulatory personnel when conducting pest survey and control programs against the *Dendrolimus* moths:

- Pine-tree lappet, *Dendrolimus pini* (L.)
- Masson pine caterpillar, *Dendrolimus punctatus* (Walker)
- Siberian silk moth, *Dendrolimus sibiricus* Tschetverikov
- Sakhalin silk moth, *Dendrolimus superans* (Butler)

Instructions to Officials

Agricultural officials must follow instructions for regulatory treatments or other procedures when authorizing the movement of regulated articles. Understanding the instructions and procedures is essential when explaining procedures to people interested in moving articles affected by the quarantine and regulations. Only authorized treatments can be used in line with labeling restrictions. During all field visits, ensure that proper sanitation procedures are followed as outlined in *Preparation, Sanitization, and Clean-Up* on page 4-2.

Regulatory Actions and Authorities

After an initial suspect positive detection, an Emergency Action Notification may be issued to hold articles or facilities, pending positive identification by a USDA–APHIS–PPQ-recognized authority and/or further instruction from the PPQ Deputy Administrator. If necessary, the Deputy Administrator will issue a letter directing PPQ field offices to initiate specific emergency action under the Plant Protection Act until emergency regulations can be published in the *Federal Register.*

The Plant Protection Act of 2000 (Statute 7 USC 7701-7758) provides the authority for emergency quarantine action. This provision is for interstate regulatory action only; intrastate regulatory action is provided under State authority.

State departments of agriculture normally work in conjunction with Federal actions by issuing their own parallel hold orders and quarantines for intrastate movement. However, if the U.S. Secretary of Agriculture determines that an extraordinary emergency exists and that the States measures are inadequate, USDA can take intrastate regulatory action provided that the governor of the State has been consulted and a notice has been published in the Federal Register. If intrastate action cannot or will not be taken by a State, PPQ may find it necessary to quarantine an entire State.

PPQ works in conjunction with State departments of agriculture to conduct surveys, enforce regulations, and take control actions. PPQ employees must have permission of the property owner before entering private property. Under certain situations during a declared extraordinary emergency or if a warrant is obtained, PPQ can enter private property without owner permission. PPQ prefers to work with the State to facilitate access when permission is denied, however each State government has varying authorities regarding entering private property.

A General Memorandum of Understanding (MOU) exists between PPQ and each State that specifies various areas where PPQ and the State department of agriculture cooperate. For clarification, check with your State Plant Health Director (SPHD) or State Plant Regulatory Official (SPRO) in the affected State. Refer to *Resources* on page A-1 for information on identifying SPHD's and SPRO's.

Tribal Governments

USDA–APHIS–PPQ also works with federally-recognized Indian Tribes to conduct surveys, enforce regulations and take control actions. Each Tribe stands as a separate governmental entity (sovereign nation) with powers and authorities similar to State governments. Permission is required to enter and access Tribal lands.

Executive Order 13175, Consultation and Coordination with Indian and Tribal Governments, states that agencies must consult with Indian Tribal governments about actions that may have substantial direct effects on Tribes. Whether an action is substantial and direct is determined by the Tribes. Effects are not limited to Tribal land boundaries (reservations) and may include effects on off-reservation land or resources which Tribes customarily use or even effects on historic or sacred sites in States where Tribes no longer exist.

Consultation is a specialized form of communication and coordination between the Federal and Tribal governments. Consultation must be conducted early in the development of a regulatory action to ensure that Tribes have opportunity to identify resources which may be affected by the action and to recommend the best ways to take actions on Tribal lands or affecting Tribal resources. Communication with Tribal leadership follows special communication protocols. For more information, contact PPQ's Tribal Liaison. Refer to *Table A-1* on page A-2 for information on identifying PPQ's Tribal Liaison.

To determine if there are federally-recognized Tribes in a State, contact the State Plant Health Director (SPHD). To determine if there are sacred or historic sites in an area, contact the State Historic Preservation Officer (SHPO). For clarification, check with your SPHD or State Plant Regulatory Official (SPRO) in the affected State. Refer to *Resources* on page A-1 for contact information.

Overview of Regulatory Program After Detection

Once an initial U.S. detection is confirmed, holds will be placed on the property by the issuance of an Emergency Action Notification. Immediately put a hold on the property to prevent the removal of any host plants of the pest.

Traceback and trace-forward investigations from the property will determine the need for subsequent holds for testing and/or further regulatory actions. Further delimiting surveys and testing will identify positive properties requiring holds and regulatory measures.

Record-Keeping

Record-keeping and documentation are important for any holds and subsequent actions taken. Rely on receipts, shipping records and information provided by the owners, researchers or manager for information on destination of shipped plant material, movement of plant material within the facility, and any management (cultural or sanitation) practices employed.

Keep a detailed account of the numbers and types of plants held, destroyed, and/or requiring treatments in control actions. Consult a master list of properties, distributed with the lists of suspect nurseries based on traceback and trace-forward investigations, or nurseries within a quarantine area. Draw maps of the facility layout to located suspect plants, and/or other potentially infected areas. When appropriate, take photographs of the symptoms, property layout, and document plant propagation methods, labeling, and any other information that may be useful for further investigations and analysis.

Keep all written records filed with the Emergency Action Notification copies, including copies of sample submission forms, documentation of control activities, and related State issued documents if available.

Issuing an Emergency Action Notification

Issue an Emergency Action Notification to hold all host plant material at facilities that have the suspected plant material directly or indirectly connected to positive confirmations. Once an investigation determines the plant material is not infested, or testing determines there is no risk, the material may be released and the release documented on the EAN.

Regulated Area Requirements Under Regulatory Control

Depending upon decisions made by Federal and State regulatory officials in consultation with a Technical Working Group, quarantine areas may have certain other requirements for commercial or research fields in that area, such as plant removal and destruction, cultural control measures, or plant waste material disposal.

Any regulatory treatments used to control this pest or herbicides used to treat plants will be labeled for that use or exemptions will be in place to allow the use of other materials.

Establishing a Federal Regulatory Area or Action

Regulatory actions undertaken using Emergency Action Notifications continue to be in effect until the prescribed action is carried out and documented by regulatory officials. These may be short-term destruction or disinfestation orders or longer term requirements for growers that include prohibiting the planting of host crops for a period of time. Over the long term, producers, shippers, and processors may be placed under compliance agreements and permits issued to move regulated articles out of a quarantine area or property under an EAN.

Results analyzed from investigations, testing, and risk assessment will determine the area to be designated for a Federal and parallel State regulatory action. Risk factors will take into account positive testing, positive associated, and potentially infested exposed plants. Boundaries drawn may include a buffer area determined based on risk factors and epidemiology.

Regulatory Records

Maintain standardized regulatory records and databases in sufficient detail to carry out an effective, efficient, and responsible regulatory program.

Use of Chemicals

The PPQ *Treatment Manual* and the guidelines identify the authorized chemicals, and describe the methods and rates of application, and any special instructions. For further information refer to *Control Procedures* on page 6-1. Agreement by PPQ is necessary before using any chemical or procedure for regulatory purposes. No chemical can be recommended that is not specifically labeled for this pest.

Chapter 6

Control Procedures

Contents

Introduction

Use *Chapter 6: Control Procedures* as a guide to controlling the *Dendrolimus* moths:

- Pine-tree lappet, *Dendrolimus pini* (L.)
- Masson pine caterpillar, *Dendrolimus punctatus* (Walker)
- Siberian silk moth, *Dendrolimus sibiricus* Tschetverikov
- Sakhalin silk moth, *Dendrolimus superans* (Butler)

Consider the treatment options described within this chapter when taking action to eradicate, contain, or suppress *Dendrolimus* moths.

A successful integrated pest management system (IPM) will consider chemical, biological and cultural techniques to reduce pest populations.

Overview of Emergency Programs

Plant Protection and Quarantine develops and makes control measures available to involved States. United States Environmental Protection Agency-approved treatments will be recommended when available. If the selected treatments are not labeled for use against the pest or in a particular environment, PPQ's FIFRA Coordinator is available to explore the appropriateness in developing an Emergency Exemption under Section 18, or a State Special Local Need under section 24(c) of FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act), as amended.

The PPQ FIFRA Coordinator is also available upon request to work with EPA to rush the approval of a product that may not be registered in the United States, or to get labeling for a new use. The PPQ FIFRA Coordinator is available for guidance pertaining to pesticide use and registration. Refer to *Resources* on page A-1 for information on contacting the Coordinator.

Treatment Options

Insecticides have been used to control the population levels of *Dendrolimus* moths during outbreaks. However, biological control and biopesticides have also been used successfully. In natural conditions, biological control plays an important role in controlling outbreaks and, the diversity of biological control agents is an important component of an integrated pest management program. It is the National Program Manager's responsibility to verify that treatments are appropriate and legal for use. Upon detection and when a chemical treatment is selected, the National Program Manager should consult with PPQ's FIFRA Coordinator to ensure that the chemical is approved by EPA for use in the United States prior to application.

Treatments can include any combination of the following options:

- Sanitation
- Application of insecticides
- Other cultural control methods

Eradication

Eradication is the first action to consider with the introduction of a new pest. Eradication may be feasible under some conditions, but if it fails then other strategies will be considered. Eradication may be feasible when the following conditions exist:

- Pest population is confined to a small area
- Detection occurs soon after the introduction
- Pest population density is low

If an infestation of *Dendrolimus* moths is discovered that meets the above named conditions, eradication will be attempted. Measures will include but may not be limited to removal and destruction of all infested plant material, removal of host material within 2 miles (3.2 km) of the find, and treatment of the soil and surrounding vegetation with an approved pesticide after removal of the infested plants.

Cultural Control

Sanitation

When visiting fields to conduct surveys or take samples, everyone (including regulatory officials) must take strict measures to prevent contamination by *Dendrolimus* moths between properties during inspections. Before entering a new property make certain that footwear and clothing are clean and free of soil and bugs to avoid moving moths from one property to another.

Carry out sanitation in forests, nurseries, gardens, landscapes, fields, and other establishments where hosts are present within the core and buffer areas. Depending on the circumstances and equipment available, use the following techniques:

- Clean cultivation
- Burning of host plants
- Field sanitation

Rely on a combination of cultural and biological control methods in nonemergency situations. Cultural control may be subject to obtaining environmental documentation under the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). Check with the program manager to make sure such documentation is in order.

Barriers

10cm wide vinyl tape may be wrapped around trees at the base to impede the movement of caterpillars up the tree at the end of winter. This simple procedure results in a reduction of between 65 to 79% of the larvae of *Dendrolimus superans* and a corresponding reduction in damage to the tree (Higashiura, 1991). A variation of the above is to add a 1¼ cm strip of waterproof material just below the tape and run it sideways up the tape to just about the middle of the tape at a point halfway across the trunk and hang a net there to catch caterpillars crawling up the strip and falling into the net. This will provide a population estimation of the pest population (Fukuyama, 1978). Both the above two procedures will expose caterpillars to predators and parasites.

Strings treated with 2.5% deltamethrin or 20% pyrethroids with diesel oil and machine oil (3:80:20) are wrapped around trees at the base in April or May when *Dendrolimus superans* caterpillars are gathered around the bottom of the trunks and ready to climb. This is also when these larvae are very weak after the winter. This technique produces a mortality rate of 100%. Sunshine or rain does not affect the results (Guo et al., 1984).

Note: These techniques are labor intensive and should be used only if the infected area is very limited in extent and/or there is a real chance of eliminating the invasive population by interrupting the life cycle in this manner.

Suppression

Pest management includes steps taken to either contain or suppress a pest population. Damage attributed to *Dendrolimus* moths is most effectively managed with the controls described below.

Chemical Control

Insecticides

Pesticides play an important role in controlling population outbreaks of *Dendrolimus* in natural and commercial forest stands. Considerations should be taken into account when using pesticides because of their effect on non-target organisms including natural populations of parasitoids and predators. When using pesticides, it is also important to consider the non-target effect of soil-inhabiting biological control agents that play an important role in controlling larva that hibernate (fungi and bacteria) and those predators that feed on the larva that fall from the tree canopy due to wind or other natural causes (Jakel and Roth, 1998). Pesticides used to control *Dendrolimus* moths are primarily pyrethroids, insect growth regulators or biopesticides and are applied as Ultra Low Volume (ULV) formulations to increase their coverage and efficacy (Sierpinska, 1998; Sierpinska and Sierpinski, 1995). Sprays are more effective when treatment occurs in the spring and fall to coincide with active feeding by the larva. Spring sprays are preferable to allow more time for biological control agents to have an effect on moth populations and to conduct population monitoring.

Dendrolimus pini

Ultra low volume aerial sprays of pine stands in forests in Poland using zeta cypermethrin resulted in a 80% mortality of PTL two days after spraying and 99% mortality seven days after spraying (Sierpinska, 1998). Sierpinska, 1998) also tested commercial preparations of biopesticides formulated from selected strains of *Bacillus thuringiensis* and found mortality rates comparable (97%) to those using pyrethroid formulations; however, this mortality rate was observed 23 days after spraying.

Table 6-1 Insecticides Available For Use to control *Dendrolimus* moths in the United States[1]

Pesticide Common Name	Type/Strain	Registered for use in United States	Reference
Pyrethroids			
Deltamethrin	Contact	Yes	Sierpinska, 1998; Woreta and Malinowski, 1998; (Alekseev and Chankina, 1998); Guo et al., 1984

Table 6-1 Insecticides Available For Use to control *Dendrolimus* moths in the United States[1]

Pesticide Common Name	Type/Strain	Registered for use in United States	Reference
Lambda-cyhalothrin	Contact	Yes	Moeller and Engelmann, 2008; Sierpinska, 1998 Woreta and Malinowski, 1998
Esfenvalerate	Contact	Yes	Sierpinska, 1998; Guo et al., 1984
Etofenprox	Contact	Yes	Sierpinska, 1998
Zeta-cypermethrin	Contact	Yes	Sierpinska, 1998 Woreta and Malinowski, 1998
Insect Growth Regulators			
Diflubenzuron	Chitin-inhibiting	Yes	Sierpinska, 1998 Miao et al., 1989; Moeller and Engelmann, 2008;Liang et al., 1999
Biopesticides			
Bacillus thuringiensis	Kurstaki HD-1	Yes	Sierpinska, 1998 2002; Talalaev, 1959, 1962
Bacillus thuringiensis	EG 2348	Yes	Moeller and Engelmann, 2008; Sierpinska, 1998
Other groups			
Azadirachtin		Yes	Dobrowolski, 2002; Malinowski et al., 1998

1 All treatments listed in the guidelines should only be used as a reference to assist in the regulatory decision making process. It is the National Program Manager's responsibility to verify that treatments are appropriate and legal for use. Upon detection and when a chemical treatment is selected, the National Program Manager should consult with PPQ's FIFRA Coordinator to ensure that the chemical is approved by EPA for use in the United States prior to application.

Pyrethroids

Synthetic pyrethroids are available for control, including Lambda-cyhalothrin (Moeller and Engelmann, 2008; Sierpinska, 1998; Woreta and Malinowski, 1998), esfenvalerate, etofenprox, deltamethrin, and zeta-cypermethrin (Reviewed in Sierpinska, 1998).

Insect Growth Regulators

Aerial sprays of diflubenzuron during an outbreak resulted in a 90% mortality rate in a 790 ha section of the Piska Primaeval Forest, while aerial sprays of teflubenzuron over 2101 ha in the Bydgoska Primaeval Forest in Poland resulted in 90-96% mortality (Adomas, 1997, 2003). Diflubenzuron is a molting inhibitor which has been shown to have reliable efficiency against *Dendrolimus superans* (Miao et al., 1989). If a colloidal suspension is used, it is even more efficient, as the solution holds together against rain and is effective for about 20-30 days. This suspension was shown to be quite effective against *D. spectabilis* and *D. tabulaeformis* (Miao and Zhang, 1986).

Biopesticides

Bacillus thuringiensis

Bacillus thuringiensis is a Lepidoptera-specific microbial that, when ingested, disrupts the midgut membranes. Certain strains have shown some efficacy against *Dendrolimus* spp., notably *Bacillus thuringiensis* var. *kurstaki* (Btk) has shown mortality rates comparable (97%) to using pyrethroid formulations. This mortality rate was observed, however, 23 days after spraying (Sierpinska, 1998). Some Bt strains are specific for SSM, such as strain L-93 (Zhao et al., 1998a; Zhao et al., 1998b) or strain BtMP-342 (Shukui et al., 1996).

Apply as a full-coverage spray when larvae are present. Repeat at 10 to 14 day intervals while larvae are active. Effectiveness of aerial delivery is enhanced if done by helicopter, since the downdraft turns the needle surfaces for better exposure.

Azadirachtin

Azadirachtin is the key insecticidal ingredient found in neem tree (*Azadirachta indica*) oil. It is structurally similar to ecdysones, insect hormones that control metamorphosis. After ingestion, insects stop feeding; however, death may not occur for several days. Azadirachtin has been shown to be effective on *Dendrolimus* larvae and pupae (Malinowski et al., 1998; Dobrowolski, 2002).

Timing of applications

Apply an insecticide immediately upon discovery of a *Dendrolimus* moth detection. Apply insecticides in the late afternoon, evening or at night to coincide with the nocturnal habits of adults.

Consider delaying applications if weather reports indicate greater than 50% chance of precipitation within 48 hours after application. If rain reduces the effectiveness of an application, retreat the area immediately, or as soon as the label permits.

After an estimated two generations of negative trapping and survey, applications may be discontinued and monitoring should resume to determine the effectiveness of eradication.

Biological Control

In natural conditions, biological control plays an important role in regulating the population densities of all *Dendrolimus* moths and in some cases, in suppressing outbreaks. Biological control is an important component of an integrated pest management approach in forest ecosystems. Natural biological control agents include parasitoid and predatory arthropods, entomopathogens like *Bauveria bassiana*, and nuclear and cytoplasmic polyhedrosis viruses, among others. For example, mortality of hibernating PTL larva in two-year life cycle populations was as high as 94% because of high parasitism by the tachinid fly *Masicera cuculliae* Robineau-Desvoidy and the fungus *B. bassiana* (Malyshev, 1987). Application of microorganisms, particularly insect viruses has provided some of the most effecting methods for integrated pest management of *Dendrolimus* moths.

To a lesser extent, vertebrates like birds, bats and chipmunks are also important for example, during the 1956 outbreak of SSM in Siberia a large number of pupae were consumed by jackdaws (Boldaruev, 1959).

Egg Parasitoids

Dendrolimus pini

In Germany during the 1934 and 1935 outbreak the percentage of PTL pupa parasitized increased from 20% to 58% in the spring and resulted in a significant population reduction in the fall (Varley, 1949). In the state of Brandenburg, Germany, mortality rate of PTL was as high as 100% due to egg parasitism by the parasitic wasp *Telenomus laeviusculus* (Ratzeburg)(Moeller and Engelmann, 2008). In Russia, hymenopteran and dipteran parasitoids have played an important role in controlling PTL. *Telenomus tetratomus* Keiffer was found parasitizing 54% of eggs with as many as 17 maggots / egg and *Trichogramma embryophagum* (Hartig) parasitism was 65% (Malyshev, 1996).

Dendrolimus punctatus

Trichogramma dendrolimi Matsumura is a major egg parasitoid of *D. punctatus* (Lung, 1957). The large scale propagation and release of *T. dendrolimi* has been responsible for 80 to 85% parasitism levels and resulted in effective suppression of *Dendrolimus* populations in China (Wu et al., 1988). *Anastatus* spp. are regarded as another good biological agent for controlling the MPC (Chen and Lee, 1985). *Anastatus albitarsis* Ashmead released at 45,000 wasps/ha has led to levels as high as 68% parasitism of the first generation of MPC (Tong and Ni, 1989).

By additional supplementation with eggs from an alternative host, the saturniid moth *Antheraea pernyi* (Guérin-Méneville), researchers increased *T. dendrolimi* populations and the parasitism rates on MPC (Tong et al., 1988). When silkworm eggs were supplemented 3 times per month throughout the year, the population density of the parasitoid was 1.4 times higher than when egg supplements were made twice monthly before the appearance of MPC eggs. Different methods of supplementing host eggs are suggested for forests of different ecological characteristics. More frequent supplements of host eggs are needed for forests with less vegetation cover (see Tong et al., 1988).

Dendrolimus sibiricus

Egg parasitoids found attacking SSM include *Telenomus gracilis* Mayr, *T. tetratomus*, *Trichogramma dendrolimi* and *Ooencyrtus pinicolus* (Matsumura). Reported egg parasitism of SSM under natural conditions has been as high as 97% (EPPO, 2005; Nikiforov, 1970; Yu, 1982).

Dendrolimus superans

In China, the use of *Trichogramma dendrolimi* to control SSM has been effective with reported egg parasitism levels as high as 97%, and with levels of parasitism as high as 76% with the release of only 550 wasps per ha (Yu, 1982). Enu (1982), discussed *Trichogramma* releases against *D. superans* and found timing *Trichogramma* releases to be extremely important in success. The emergence period of the wasps must coincide with the oviposition period of the moths. The quality of the parasites released and the times of release are decided on the basis of host population levels. The two species under consideration are *T. semblidis* (Aurivillius) and *T. dendrolimi.* The latter is commercially produced in Germany as given in Appendix B: Resources. There is a third *Trichogramma* parasite (Kolomiec, 1962), but not much is known about its biology. Unfortunately, other parasites have not been developed for mass production and release and it may be necessary to test some of the larval and pupal parasites listed above in order to determine what impact they could have on pest population suppression.

Larval Parasitoids

The impact of parasitoids on the larval stage differs with the level of outbreak and location of insect species determining the effectiveness of these natural regulators upon pest population density. A listing of the more important *Dendrolimus* parasites is provided in Appendix A.

Dendrolimus pini

Numerous parasitic insects have been noted to attack PTL larvae including *Agria* (Pseudosarcophaga) *affinis* (Fallen), *Nemorilla floralis* (Fallen) and *Sturmia inconspicua* (Meigen), *Tricolyga segregata* Rondani, *Sarcophaga dux* (Thompson), *Tachina (Exorista) larvarum* (L.), and a braconid of the genus *Apanteles* (Melis, 1940).

For example, *A. affinis* reduced numbers of PTL larvae and pupae by 10% to 40% in Poland (Sitowski 1928). In 1947-48 and 1956-57, because of high parasitism of pine moth larvae by *Apanteles* sp. and *Meteorus* sp., the Polish forest administration decided not to initiate control treatments (Sliwa 1992). In stands where sticky bands were used as a method of PTL control, *Muscina pabulorum* Fallen parasitized 40-to 60% of pine moth larvae in the first year and *Stomoxys calcitrans* L. parasitized up to 30% of the larvae (Sierpinska, 1998).

Dendrolimus punctatus

Ichneumonid wasps are important parasitoids of the larvae and pupae of Masson pine caterpillar. A study from China conducted from 1983 to 1984 found parasitism by *Casinaria nigripes* (Gravenhorst) to be an important factor in mortality of the MPC. The ichneumonid had five generations a year and overwintered in the larval stage in the third to fourth larval instar of the host (Qian, 1987). *C. nigripes* parasitism was reported to range from 67% parasitism in Hunan province (Ma et al.,1989) to 23% to the third generation of D. punctatus in Jiangsu province (Qian, 1987; CABI, 2011b).

The uji fly, *Blepharipa zebina* Walker, is commonly found in MPC larvae and pupae (CABI, 2011b). Wong and Zhou (1995) reported parasitic rates by *Carcelia matsukarehae* Shima, *B. zebina* and *Sarcophaga beesoni* Senior-White on the second generation of MPC as 14, 16, and 34%, respectively, in Guangdong province. The tachinid *Exorista xanthaspis* (Wiedemann) is another parasitoid of the forest pest of MPC. Having five to six generations a year, parasitism of MPC in the first, second and third generations was 22, 45 and 1%, respectively. Most of the eggs were laid on the hosts' prothoracic legs, with 1 to 33 eggs being placed on each host. Some of the hosts (3%) were able to survive parasitism if they had an average of 2.5 eggs or less. In the field in China fluctuations in the parasitoid population were positively correlated with temperature during May but negatively correlated in late July to early August (Ma et al., 1988).

Dendrolimus sibiricus

Larval and pupal parasitoids such as *Rhogas dendrolimi* Matsumura and *Masicera zimini* Kolomeits have been shown to be very important parasitoid of SSM pupae in Siberia with parasitism level reaching 80% (Rozhkov, 1961). *Apanteles* sp. and *Carcelia excisa* (Fallen) are important biocontrol agents of SSM and SaSM in Japan and Russia with levels of parasitism as high as 85% (EPPO, 2005; Matsumura, 1926a, 1926b). Boldaruev (1958) reported parasitism efficiencies between 65 and 85% in natural populations of low (1 to 20 larvae/tree) and high (100 to 500 larvae/tree) densities of SSM larvae. However, mass-rearing and release of these parasitoids is time consuming (Boldaruev, 1958).

Dendrolimus superans

A suite of larval parasitoid have been found emerging from SaSM larvae, including such generalists that are used in biological control including *Theronia atalantae* (Poda), *Glyptapanteles liparidis* (Marsh) and *Apanteles ordinarius* Ratzeburg (Fukuyama, 1980.

The tachinid *Masicera zimini* Kolomiets has been reported to attack SaSM. Adults of *M. zimini* were present in August and part of September, with females laying eggs on the needles of the trees which are apparently ingested by host larvae in the first instar with their food. The life-cycle lasts two years, with the larvae overwintering twice. On an average the parasitism rate varied from 20 to 63% (Boldaruev, 1952).

A braconid wasp, *Rhogas dendrolimi* (Matsumura) has also been found to parasitize SaSM and SSM larvae. *R. dendrolimi*, like *M. zimini*, had a two-year life-cycle. Parasitized moth larvae hibernated and reached the fourth instar at the same time as non-parasitized individuals, but their development then ceased almost completely. These parasitized larvae hibernated a second time, but ceased feeding in the following May and crawled about on the lower parts of the trees. The parasitized larvae resumed feeding in spring, killed their hosts by gnawing a hole through the thorax, glued them to the trunks by means of a liquid ejected through the hole, and completed their development in the remains (Boldaruev, 1952).

Predators

Predators including insects, birds, and mammals are also important biological control agents in a forest ecosystem (Sierpinska, 1998). Ants such as *Formica polyctena* Foerster and *F. nigricans* Emery have shown to be effective biological control agents for first and second instar larva of *Dendrolimus* moths (Malysheva, 1963). Ants are important natural enemies of young *Dendrolimus* larvae. Predation on first, second and third instar larvae on the forest floor by *Camponotus japonicus* Mayr was 70, 23, and 10%, respectively (Wang et al., 1991). Similarly, predation by *Formica japonica* Motschoulsky was 47, 27 and 10%, respectively (Wang and Wu, 1991). In Guangxi, China, *Polyrhachis dives* Smith and *Crematogaster artifex* Mayr build nests in trees or on the ground. In stands where these ants are common, *D. punctatus* seldom reach large numbers (Chen, 1990). Other important predatory enemies include praying mantis, wasps, katydids, predatory true bugs (e.g., Pentatomidae, Reduviidae), spiders and birds (CABI, 2011b) (Refer to Appendix D for more detailed lists.

Microorganisms

Representatives of the genus *Dendrolimus* are carriers of the *Dendrolimus* cytoplasmic polyhedrosis virus (DsCPV-1) and susceptible to infection by the virus from another closely related species. Data has been presented on the virulence of *D. pini* DsCPV-1 for D. *spectabilis* and D. *superans* (Chkhubianishvili and Katagiri, 1983). Other *Dendrolimus* moth species isolated with the same virus include *D. punctatus*, *D. tabulaeformis*, *D. p. tehchangensis*, and *D. p. wenhangensis*. (Zhao et al., 2004b)

This approach is still under study. It should be possible to produce and release this virus in the quantity required to seriously affect any invasive *Dendrolimus* moth population and should be incorporated into an IPM system when available

Dendrolimus pini

Detailed descriptions of entomopathogenic fungi used to control forest insects including PTL are found in Malinowski, 2009) and in Sierpinska, 1998). *Beauveria brongniartii*, *B. bassiana*, *Paecilomyces farinosus*, *Metarhizium anisopliae* and *Verticillium lecanii* have shown good control of forest pests. *Cordyceps militaris* is also an important biocontrol agent of hibernating larvae causing up to 80% mortality (Sierpinska, 1998). During the outbreak of 1996 in Lithuania's forests, *C. militaris* was found in 70% of hibernating larva, causing up to 66% mortality (Gedminas, 2000). Fungi are highly dependent on humidity for their effective control.

Among bacteria, *Bacillus thuringiensis* preparations are the most widely used to control the PTL (Moeller and Engelmann, 2008; Sierpinska, 1998) (see *Chemical Control* on page 6-5).

The introduction and establishment of the granulosis virus (GV) of *D. sibiricus* into populations of PTL resulted in the mortality of 65-80% of pupa and a significant reduction of PTL populations in Voronezh, Russia. The establishment of the virus caused a prolonged suppression of populations for 22 years (Orlovskaya, 1998). This method is based on the inoculation of eggs with viral preparations and its release in the forest for further dissemination. The cytoplasmic polyhedrosis virus of the pine moth, *Dendrolimus pini* L (CPVPTL) is another potential biological control agent (Slizynski and Lipa, 1975). In laboratory tests, the mortality of PTL second instar larva inoculated with 6.8 x10^6 polyhedral inclusion bodies/larva was as high as 100% (Slizynski and Lipa, 1975).

Other Lepidoptera of the families Lymantridae and Lasiocampidae were also affected by CPVPTL with comparable levels of mortality (Slizynski and Lipa, 1975). Viral preparations have also been used and applied as pesticides but this is a more expensive approach because of the high costs associated with the mass production of virus (Orlovskaya, 1998).

Dendrolimus punctatus

Microorganism-based control methods against the MPC have been successful when achieved using multiple agents including cytoplasmic polyhedrosis virus of *D. spectabilis* from Japan (Chang, 1991), and an insect parasitic fungus (*Isaria* sp.) isolated from infected bodies of pine caterpillar collected in local pine forests (Ying, 1986b) and the entomopathogenic fungus *B. bassiana* (Lu et al., 2008). Microbial pesticides made from *B. bassiana* are commonly used to suppress high larval populations of *D. punctatus* in China (Pan et al., 1983). *Metarhizium anisopliae* has similar toxicity against MPC and may be superior to *B. bassiana* in certain environmental conditions (Jiang, 2000). Other methods of control include *Bt* and a cytoplasmic polyhedrosis virus (Chen et al., 1997; Hou, 1986; Zhao et al., 2000). Cytoplasmic polyhedrosis virus (CPV) powder applied at a rate between 3.0 and 7.5 billion polyhedra/ha provided an average 63% population reduction of third to fifth instar larvae (Fan and Jiang, 1983). Peng et al. (Peng et al., 1998) reported that *Trichogramma dendrolimi* carrying *D. punctatus* CPV can significantly increase the control efficacy (CABI, 2011b).

Dendrolimus sibiricus

A variety of microorganisms can be used against SSM including *Bacillus thuringiensis* var. *kurstaki, B. dendrolimus, B. thuringiensis* subsp. *dendrolimus (sotto)* (Bacteria), *B. bassiana* (fungi) and DsCPV and DsNPV (cytoplasmic and nuclear polyhedrosis viruses) (EPPO, 2005 Koyama, 1961; Shternshis, 2005). Preparations of Bt subspecies provided the basis for the formulation of several commercial products used for the control of forest pests in Russia (Shternshis, 2005; Talalaev, 1959, 1962).

Dendrolimus superans

A specific cytoplasmic polyhedrosis virus isolated from *D. spectabilis* was described in 1956 and has shown strong virulence for that species as well as *D. superans* (Koyama, 1961. As with other species of *Dendrolimus* considered here, there is a high degree of cross-specific activity for CPVs as at least 6 isolates have been found (Chkhubianishvili Ts and Katagiri, 1983; Zhao et al., 2004a).

Integrated Pest Management

Integrated pest management approaches to manage and control established populations of pine-tree lappet have been suggested and described by Sierpinksa (Sierpinska, 1998). The goal of these programs is to establish a healthy forest ecosystem that will promote the existence of natural populations of insect parasitoids and predators, entomopathogenic microorganisms (fungi, bacteria and viruses), insectivorous birds and bat populations. Creating the environmental conditions that favor the existence of these biological control agents will greatly help in controlling pine-tree lappet populations and minimize the use of pesticides. An IPM program for *Dendrolimus* moths may include combinations of frequent monitoring (suggested at five to seven times/year in high risk areas), establishment of surveys to monitor economic thresholds, limiting impacts from human activities, use of light traps to reduce moth populations, and applying biological pesticides to reduce larval population levels (Chen, 1990). When possible, different pine species or mixed tree species are recommended in forestry programs. For example, short-term approaches in Vietnam focused on biological control, including mass production and application of microbial agents and parasitic insects. Recommended long-term strategies have included establishing mixed stands of different pine species or pines and broad-leaved trees, or to replace pines with non-host species in high-hazard areas, increases in fire prevention, and enhanced training of protection personnel in all phases of integrated pest management (Billings, 1991).

Summary

The most effective control program for suppression of *Dendrolimus* moths will likely incorporate the use of chemical and biological control measures in an integrated pest management approach.

If an established population is found in a coniferous forest production area, a science advisory panel will be asked to determine the best course of action. If eradication is not possible, as determined by the science advisory panel, it will be the responsibility of University extension services to determine the best management practices.

Environmental Documentation and Monitoring

Obtain all required environmental documentation before beginning. Contact Environmental Services Staff for the most recent documentation. For further information, refer to *Environmental Compliance* on page 7-1.

Chapter 7

Environmental Compliance

Contents

Introduction

Use Chapter 7 Environmental Compliance as a guide to the *Dendrolimus* moths:

- Pine-tree lappet, *Dendrolimus pini* (L.)
- Masson pine caterpillar, *Dendrolimus punctatus* (Walker)
- Siberian silk moth, *Dendrolimus sibiricus* Tschetverikov
- Sakhalin silk moth, *Dendrolimus superans* (Butler)

Overview

Program managers of Federal emergency response or domestic pest control programs must ensure that their programs comply with all Federal Acts and Executive Orders pertaining to the environment, as applicable. Two primary Federal Acts, the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA), often require the development of significant documentation before program actions may begin.

Program managers should also seek guidance and advice as needed from Environmental and Risk Analysis Services (ERAS), a unit of APHIS' Policy and Program Development (PPD) staff. ERAS is available to give guidance and advice to program managers and prepare drafts of applicable environmental documentation.

In preparing draft NEPA documentation ERAS may also perform and incorporate assessments that pertain to other acts and executive orders described below, as part of the NEPA process. The Environmental Compliance Team (ECT), a part of PPQ's Emergency Domestic Programs (EDP), will assist ERAS in the development of documents, and will implement any environmental monitoring.

Leaders of programs are strongly advised to meet with ERAS and/or ECT early in the development of a program in order to conduct a preliminary review of applicable environmental statutes and to ensure timely compliance. Environmental monitoring of APHIS pest control activities may be required as part of compliance with environmental statutes, as requested by program managers, or as suggested to address concerns with controversial activities. Monitoring may be conducted with regards to worker exposure, pesticide quality assurance and control, off-site chemical deposition, or program efficacy. Different tools and techniques are used depending on the monitoring goals and control techniques used in the program. Staff from ECT will work with the program manager to develop an environmental monitoring plan, conduct training to carry out the plan, give day-to-day guidance on monitoring, and provide an interpretive report of monitoring activities.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires all Federal agencies to examine whether their actions may significantly affect the quality of the human environment. The purpose of NEPA is to inform the decisionmaker before taking action, and to tell the public of the decision. Actions that are excluded from this examination, that normally require an Environmental Assessment, and that normally require Environmental Impact Statements, are codified in APHIS' NEPA Implementing Procedures located in 7 CFR 372.5.

The three types of NEPA documentation are Categorical Exclusions, Environmental Assessments, and Environmental Impact Statements.

Categorical Exclusion

Categorical Exclusions (CE) are classes of actions that do not have a significant effect on the quality of the human environment and for which neither an Environmental Assessment (EA) nor an environmental impact statement (EIS) is required. Generally, the means through which adverse environmental impacts may be avoided or minimized have been built into the actions themselves (7 CFR 372.5(c)).

Environmental Assessment

An Environmental Assessment (EA) is a public document that succinctly presents information and analysis for the decisionmaker of the proposed action. An EA can lead to the preparation of an environmental impact statement (EIS), a finding of no significant impact (FONSI), or the abandonment of a proposed action.

Environmental Impact Statement

If a major Federal action may significantly affect the quality of the human environment (adverse or beneficial) or the proposed action may result in public controversy, then prepare an Environmental Impact Statement (EIS).

Endangered Species Act

The Endangered Species Act (ESA) is a statute requiring that programs consider their potential effects on federally-protected species. The ESA requires programs to identify protected species and their habitat in or near program areas, and document how adverse effects to these species will be avoided. The documentation may require review and approval by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service before program activities can begin. Knowingly violating this law can lead to criminal charges against individual staff members and program managers.

Migratory Bird Treaty Act

The statute requires that programs avoid harm to over 800 endemic bird species, eggs, and their nests. In some cases, permits may be available to capture birds, which require coordination with the U.S. Fish and Wildlife Service.

Clean Water Act

The statute requires various permits for work in wetlands and for potential discharges of program chemicals into water. This may require coordination with the Environmental Protection Agency, individual States, and the Army Corps of Engineers. Such permits would be needed even if the pesticide label allows for direct application to water.

Tribal Consultation

The Executive Order requires formal government-to-government communication and interaction if a program might have substantial direct effects on any federally-recognized Indian Nation. This process is often incorrectly included as part of the NEPA process, but must be completed before public involvement under NEPA. Staff should be cognizant of the conflict that could arise when proposed Federal actions intersect with Tribal sovereignty. Tribal consultation is designed to identify and avoid such potential conflict.

National Historic Preservation Act

The statute requires programs to consider potential impacts on historic properties (such as buildings and archaeological sites) and requires coordination with local State Historic Preservation Offices. Documentation under this act involves preparing an inventory of the project area for historic properties and determining what effects, if any, the project may have on historic properties. This process may need public involvement and comment before the start of program activities.

Coastal Zone Management Act

The statute requires coordination with States where programs may impact Coastal Zone Management Plans. Federal activities that may affect coastal resources are evaluated through a process called Federal consistency. This process allows the public, local governments, Tribes, and State agencies an opportunity to review the Federal action. The Federal consistency process is administered individually by states with Coastal Zone Management Plans.

Environmental Justice

The Executive Order requires consideration of program impacts on minority and economically disadvantaged populations. Compliance is usually achieved within the NEPA documentation for a project. Programs are required to consider if the actions might impact minority or economically disadvantaged populations and if so, how such impact will be avoided.

Protection of Children

The Executive Order requires Federal agencies to identify, assess, and address environmental health risks and safety risks that may affect children. If such a risk is identified, then measures must be described and carried out to minimize such risks.

Chapter 8

Pathways

Contents

Introduction

Use *Chapter 8: Pathways* as a source of information on the pathways of introduction of the *Dendrolimus* spp. moths in the United States, including *Dendrolimus pini* (L.) Pine-tree lappet; *Dendrolimus punctatus* (Walker), Masson pine caterpillar; *Dendrolimus sibiricus* Tschetverikov, Siberian silk moth; and *Dendrolimus superans* (Butler), Sakhalin silk moth.

Overview

The entry and establishment of *Dendrolimus* moths poses a serious threat to the United States coniferous forests and to those industries that rely on forest species like the Christmas tree industry. In the US, several species of conifers with significant value for timber, Christmas trees and wood by-products are listed as natural hosts for this pest. With the increase volume of international trade and passengers arriving to the United States, the risk of unintentional introductions of pine-tree lappet increases. *Dendrolimus* moths have not been reported in this United States by the time this report was written.

Geographical Distribution

Dendrolimus pini

Currently found across Europe, Asia, and North Africa, Pine-tree lappet has a natural range that matches its primary host, Scots pine (*Pinus sylvestris*). Both temperate coniferous and mixed (coniferous and deciduous) forests are considered to be at risk for spread of PTL, within the United States. These forests make up a considerable portion (47%) of the U.S. forest, including the southern Appalachian mountain range, the Northeast, Midwest (Minnesota, Michigan, Wisconsin, North Dakota), the northwest regions of the United States and Alaska (Davis et al., 2008) (Refer to *Potential Distribution* on page 2-11 and *Figure 2-1* on page 2-9).

Dendrolimus punctatus

The Masson pine caterpillar occurs across southeastern Asia, including eastern China, Taiwan, and Vietnam (Billings, 1991; Chang, 1991; Matsumura, 1926a). The northern limit is approximately 33 degrees latitude (Ya-Jie et al., 2005), with a western limit in China of Sichuan province (CABI, 2011b).

Dendrolimus sibiricus

At present, SSM is expanding its habitat, now occupying coniferous forest of the Russian Plain (Gninenko, 2000) including China, Kazakhstan, Korea, Mongolia, and Russia (EPPO, 2005; Molet, 2012; Orlinskii, 2000). In connection with global processes of climate change, there is a risk of the expansion of this pest into northern and north-eastern regions of Siberia, including coniferous forests of Kamchatka and the Magadan region where it will be very difficult to control (CABI, 2011a). The pattern of movement of this pest into forests of Eastern Europe is occurring naturally. The transportation of forest products, especially of round wood, has little influence on the rate of spread of SSM to new regions (CABI, 2011a).

Dendrolimus superans

The present worldwide distribution of SaSM is restricted to Japan (Hokkaido and Northern Honshu) (EPPO, 2005; Fukuyama, 1980; Maeto, 1991) and far eastern Russia, including the Sakhalin and Kurile Islands (Fukuyama, 1980) (*Figure 2-1* on page 2-9).

Destinations

When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. 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-AQAS, 2007). Some portion of each of state identified as the intended final destination has a climate and hosts that would be suitable for establishment by these moths (Davis et al., 2005)

Establishment and Spread

In its native range, these insects damage more than 20 species of trees in several genera including *Pinus, Abies, Larix, Picea* and *Tsuga*. These host genera are also widely distributed in North America, but there is uncertainty about the ability to utilize congeneric hosts. *Dendrolimus* moths are found across a wide climatic range and are considered the most important pest of coniferous forests in Russia (from the center of European Russia to the Far East), Kazakhstan, Northern China, Korea and Northern Mongolia.

Both males and females fly and can disperse over long distances either on their own or assisted by air currents. Larvae are also subject to wind dispersal. In Russia this insect is presently extending its range westward at the rate of between 12 and 50 km per year. All *Dendrolimus* spp. have a high reproductive potential. Females lay an average of 200-300 eggs. Conifer forests have more or less continuous distributions in North America, especially in the boreal forests of Canada and the Western and Northeastern forests of the United States. Populations could go undetected, especially in remote areas and eradication techniques would be logistically difficult and probably ineffective. This insect has a broad host range and could adapt to many North American conifers. (Orlinskii, 2000).

Natural Spread

Natural introductions of pine tree lappet due to wind, flight and/or other natural causes to the continental United States are very unlikely. Unlike females, males are strong fliers and have been reported to fly from continental Europe to the Southern coast of the United Kingdom (Moore, 2009). A transoceanic flight from Europe to the United States is, however, very unlikely

Officers with USDA-APHIS and the Department of Homeland Security reported only one interception of *Dendrolimus* sp. at US ports of entry from 1984-2006 (USDA-AQAS, 2007). This interception was from a shipment of 2 branches of *Pinus* sp. in baggage from Japan coming into Hawaii on March 19th, 1984.

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-AQAS, 2007). The majority of interceptions (35%) were considered 'at large' or loosely associated with unspecified plants or wood and 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 (Davis et al., 2005).

Human-Assisted Spread

Human assisted pathways are probably the most likely way of introduction from Europe or Asia to the United States. In 1984, a larva of *Dendrolimus sp*. was intercepted in luggage from a passenger flying from Japan to Hawaii (USDA-AQAS, 2007). Between 1985 and 2004 twenty interceptions of insects from the Lasiocampidae family were made at ports of entry in the United States with 35% of these interceptions associated with plant material and/or wood (Selness, 2006; USDA-AQAS, 2007).

Potential human-assisted pathways include but are not limited to:

Plant material. Probably the most likely pathway. Eggs, larva and pupa can be easily transported in infested plant material and are likely to survive transport from Europe or Asia to the United States (See *Pest Information* on page 2-1). Infested plant material include:

- Live plants especially from the genus *Pinus* infested with eggs, larva, pupa or adult. It is also important to consider overwintering larva present in the soil of host plants and overwintering larva in the soil of non-host plants when these are grown in nurseries close to a forested area where pine-tree lappet outbreaks are known to occur.
- Plant parts including cut branches, foliage (Christmas trees) and logs with bark where eggs and pupal cocoons can be found.

- Contaminated vehicles and or machinery with soil or plant fragments infested with eggs and/or pupal cocoons from highly contaminated forested areas.
- Conveyances and containers: In ports close to forested areas, moths can be attracted to the light from ships or cargo planes.

People: Any life-stage of the pine tree lappet can be transported by passengers in personal equipment including clothing, tools and vehicles and/or in baggage.

The known range of *Dendrolimus* spp. in Europe and Asia normally means that this pest cannot get to the United States on its own through migratory patterns or other natural means of spread. However, the Siberian silk moth appears to have originated in Siberia but has been spreading westwards at a rate that has been variously estimated from 12 km to 40 - 50 km per year with its most western point at longitude 52° (Rozhkov, 1963). Although the SSM has been detected on the European side of Russia, east of the Ural mountain range, it has been suggested that future dispersal to most of Europe is difficult because of the lack of suitable hosts (Mikkola and Stahls, 2008). This would indicate that

Some of the uncertainty in the past about the precise distribution of *Dendrolimus* moths may derive from confusion among the species, especially between *Dendrolimus sibiricus* and *D. superans* (Orlinskii, 2000).

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Dendrolimus Pine Moths

Use *References* to learn more about the publications, Web sites, and other resources that were consulted during the production of the guidelines.

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Appendix

A

Resources

Use *Appendix A Resources* to find the Web site addresses, street addresses, and telephone numbers of resources mentioned in the guidelines. To locate where in the guidelines a topic is mentioned, refer to the index.

Table A-1 Resources for Dendrolimus Pine Moths

Resource	Contact Information
Center for Plant Health, Science, and Technology (USDA–APHIS–PPQ–CPHST)	http://www.aphis.usda.gov/plant_health/cphst/index.shtml
Emergency and Domestic Programs, Emergency Management (USDA–APHIS–PPQ–EDP–EM)	http://www.aphis.usda.gov/plant_health/plant_pest_info/index.shtml
PPQ *Manual for Agricultural Clearance*	http://www.aphis.usda.gov/import_export/plants/manuals/online_manuals.shtml
PPQ *Treatment Manual*	http://www.aphis.usda.gov/import_export/plants/manuals/online_manuals.shtml
Host or Risk Maps	http://www.nappfast.org/caps_pests/CAPs_Top_50.htm
Plant, Organism, and Soil Permits (APHIS–PPQ	http://www.aphis.usda.gov/plant_health/permits/index.shtml
National Program Manager for Native American Program Delivery and Tribal Liaison (USDA–APHIS–PPQ)	14082 S. Poston Place Tucson, AZ 85736 Telephone: (520) 822-544
Biological Control Coordinator (USDA–APHIS–CPHST)	http://www.aphis.usda.gov/plant_health/cphst/projects/arthropod-pests.shtml
FIFRA Coordinator (USDA–APHIS–PPQ–EDP)	4700 River Road Riverdale, MD 20737 Telephone: (301) 734-5861
Environmental Compliance Coordinator (USDA–APHIS–PPQ–EDP)	4700 River Road Riverdale, MD 20737 Telephone: (301) 734-7175
PPQ Form 391	http://www.aphis.usda.gov/library/forms/
List of State Plant Health Directors (SPHD)	http://www.aphis.usda.gov/services/report_pest_disease/report_pest_disease.shtml
List of State Plant Regulatory Officials (SPRO)	http://nationalplantboard.org/member/index.html
National Climatic Center, Data Base Administration, Box 34, Federal Building, Asheville, North Carolina 28801	http://www.ncdc.noaa.gov/oa/ncdc.html
CAPS Survey Manuals	http://caps.ceris.purdue.edu/
Leafhopper and treehopper genera in New Zealand	http://www1.dpi.nsw.gov.au/keys/leafhop/deltocephalinae/opsiini.htm
GenBank®	http://www.ncbi.nlm.nih.gov/
iPhyClassifier	http://plantpathology.ba.ars.usda.gov/cgi-bin/resource/iphyclassifier.cgi

Appendix

B

Forms

Use *Appendix B Forms* to learn how to complete the forms mentioned in the guidelines. To locate where in the guidelines a form is mentioned, refer to the index.

Contents

PPQ Form 391 Specimens For Determination

This report is authorized by law (7 U.S.C. 147a). While you are not required to respond your cooperation is needed to make an accurate record of plant pest conditions.

See reverse for additional OMB information.

FORM APPROVED
OMB NO. 0579-0010

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE

SPECIMENS FOR DETERMINATION

Instructions: Type or print information requested. Press hard and print legibly when handwritten. Item 1 - assign number for each collection beginning with year, followed by collector's initials and collector's number. Example (collector, John J. Dingle): 83-JJD-001.
Pest Data Section – Complete Items 14, 15 and 16 or 19 or 20 and 21 as applicable. Complete Items 17 and 18 if a trap was used.

FOR IIBIII USE
LOT NO.
PRIORITY

1. COLLECTION NUMBER
2. DATE — MO | DA | YR
3. SUBMITTING AGENCY — ☐ State Cooperator ☐ PPQ ☐ Other ______

SENDER AND ORIGIN

4. NAME OF SENDER
6. ADDRESS OF SENDER
ZIP

INTERCEPTION SITE

5. TYPE OF PROPERTY *(Farm, Feedmill, Nursery, etc.)*
7. NAME AND ADDRESS OF PROPERTY OR OWNER
COUNTRY/ COUNTY

PURPOSE

8. REASON FOR IDENTIFICATION *("x" ALL Applicable Items)*

A. ☐ Biological Control (Target Pest Name)	E. ☐ Livestock, Domestic Animal Pest
B. ☐ Damaging Crops/Plants	F. ☐ Possible Immigrant *(Explain in* REMARKS*)*
C. ☐ Suspected Pest of Regulatory Concern *(Explain in* REMARKS*)*	G. ☐ Survey *(Explain in* REMARKS*)*
D. ☐ Stored Product Pest	H. ☐ Other *(Explain in* REMARKS*)*

9. IF PROMPT OR URGENT IDENTIFICATION IS REQUESTED, PLEASE PROVIDE A BRIEF EXPLANATION UNDER "REMARKS".

HOST DATA

10. HOST INFORMATION — **NAME OF HOST** *(Scientific name when possible)*

11. QUANTITY OF HOST — NUMBER OF ACRES/PLANTS — PLANTS AFFECTED *(Insert figure and indicate* ☐ Number ☐ Percent*):*

12. PLANT DISTRIBUTION
☐ LIMITED
☐ SCATTERED
☐ WIDESPREAD

13. PLANT PARTS AFFECTED

☐ Leaves, Upper Surface	☐ Trunk/Bark	☐ Bulbs, Tubers, Corms	☐ Seeds
☐ Leaves, Lower Surface	☐ Branches	☐ Buds	
☐ Petiole	☐ Growing Tips	☐ Flowers	
☐ Stem	☐ Roots	☐ Fruits or Nuts	

PEST DATA

14. PEST DISTRIBUTION
☐ FEW
☐ COMMON
☐ ABUNDANT
☐ EXTREME

15. ☐ INSECTS ☐ NEMATODES ☐ MOLLUSKS

NUMBER SUBMITTED	LARVAE	PUPAE	ADULTS	CAST SKINS	EGGS	NYMPHS	JUVS.	CYSTS
ALIVE								
DEAD								

16. SAMPLING METHOD
17. TYPE OF TRAP AND LURE
18. TRAP NUMBER

19. PLANT PATHOLOGY – PLANT SYMPTOMS *("X" one and describe symptoms)*
☐ ISOLATED ☐ GENERAL

20. WEED DENSITY
☐ FEW ☐ SPOTTY ☐ GENERAL

21. WEED GROWTH STAGE
☐ SEEDLING ☐ VEGETATIVE ☐ FLOWERING/FRUITING ☐ MATURE

22. REMARKS

23. TENTATIVE DETERMINATION

24. DETERMINATION AND NOTES *(Not for Field Use)*

SIGNATURE
DATE

FOR IIBIII USE
DATE RECEIVED
NO.
LABEL
SORTED
PREPARED
DATE ACCEPTED
RR

PPQ FORM 391 *Previous editions are obsolete.*
(AUG 02)

This is a 6-Part form. Copies must be disseminated as follows:

☐ PART 1 – PPQ ☐ PART 2 – RETURN TO SUBMITTER AFTER IDENTIFICATION ☐ PART 3 – IIBIII OR FINAL IDENTIFIER
☐ PART 4 – INTERMEDIATE IDENTIFIER ☐ PART 5 – INTERMEDIATE IDENTIFIER ☐ PART 6 – RETAINED BY SUBMITTER

Figure B-1 Example of PPQ Form 391 Specimens For Determination, side 1

OMB Information
According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0579-0010. The time required to complete this information collection is estimated to average .25 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

Instructions
Use PPQ Form 391, Specimens for Determination, for domestic collections (warehouse inspections, local and individual collecting, special survey programs, export certification).

BLOCK	INSTRUCTIONS
1	1. Assign a number for each collection beginning the year, followed by the collector's initials and collector's number **EXAMPLE** In 2001, Brian K. Long collected his first specimen for determination of the year. His first collection number is 01-BLK-001 2. Enter the collection number
2	Enter date
3	Check block to indicate Agency submitting specimens for identification
4	Enter name of sender
5	Enter type of property specimen obtained from (farm, nursery, feedmill, etc.)
6	Enter address
7	Enter name and address of property owner
8A-8L	Check all appropriate blocks
9	Leave Blank
10	Enter scientific name of host, if possible
11	Enter quantity of host and plants affected
12	Check block to indicate distribution of plant
13	Check appropriate blocks to indicate plant parts affected
14	Check block to indicate pest distribution
15	• Check appropriate block to indicate type of specimen • Enter number specimens submitted under appropriate column
16	Enter sampling method
17	Enter type of trap and lure
18	Enter trap number
19	Enter X in block to indicate isolated or general plant symptoms
20	Enter X in appropriate block for weed density
21	Enter X in appropriate block for weed growth stage
22	Provide a brief explanation if Prompt or URGENT identification is requested
23	Enter a tentative determination if you made one
24	Leave blank

Distribution of PPQ Form 391
Distribute PPQ Form 391 as follows:
1. Send Original along with the sample to your Area Identifier.
2. Retain and file a copy for your records.

Figure B-2 Example of PPQ Form 391 Specimens For Determination, side 2

Purpose

Submit PPQ Form 391, Specimens for Determination, along with specimens sent for positive or negative identification.

Instructions

Follow the instructions in *Table B-1* on page B-5. Inspectors must provide all relevant collection information with samples. This information should be shared within a State and with the regional office program contact. If a sample tracking database is available at the time of the detection, please enter collection information in the system as soon as possible.

Distribution

Distribute PPQ Form 391 as follows:

1. Send the original along with the sample to your area identifier
2. Keep and file a copy for your records

Table B-1 Instructions for Completing PPQ Form 391, Specimens for Determination

Block	Description	Instructions
1	COLLECTION NUMBER	1. ASSIGN a collection number for each collection as follows: 2-letter State code–5-digit sample number (Survey Identification Number in Parentheses) Example: PA-1234 (04202010001) 2. CONTINUE consecutive numbering for each subsequent collection 3. ENTER the collection number
2	DATE	ENTER the date of the collection
3	SUBMITTING AGENCY	PLACE an X in the PPQ block
4	NAME OF SENDER	ENTER the sender's or collector's name
5	TYPE OF PROPERTY	ENTER the type of property where the specimen was collected (farm, feed mill, nursery, etc.)
6	ADDRESS OF SENDER	ENTER the sender's or collector's address
7	NAME AND ADDRESS OF PROPERTY OR OWNER	ENTER the name and address of the property where the specimen was collected
8A-8H	REASONS FOR IDENTIFICATION	PLACE an X in the correct block
9	IF PROMPT OR URGENT IDENTIFICATION IS REQUESTED, PLEASE GIVE A BRIEF EXPLANATION UNDER "REMARKS"	LEAVE blank; ENTER remarks in *Block 22*
10	HOST INFORMATION NAME OF HOST	If known, ENTER the scientific name of the host
11	QUANTITY OF HOST	If applicable, ENTER the number of acres planted with the host
12	PLANT DISTRIBUTION	PLACE an X in the applicable box
13	PLANT PARTS AFFECTED	PLACE an X in the applicable box
14	PEST DISTRIBUTION FEW/COMMON/ ABUNDANT/EXTREME	PLACE an X in the appropriate block
15	INSECTS/NEMATODES/ MOLLUSKS	PLACE an X in the applicable box to indicate type of specimen
	NUMBER SUBMITTED	ENTER the number of specimens submitted as ALIVE or DEAD under the appropriate stage
16	SAMPLING METHOD	ENTER the type of sample
17	TYPE OF TRAP AND LURE	ENTER the type of sample
18	TRAP NUMBER	ENTER the sample numbers
19	PLANT PATHOLOGY-PLANT SYMPTOMS	If applicable, check the appropriate box; otherwise LEAVE blank
20	WEED DENSITY	If applicable, check the appropriate box; otherwise LEAVE blank

Table B-1 Instructions for Completing PPQ Form 391, Specimens for Determination (continued)

Block	Description	Instructions
21	WEED GROWTH STAGE	If applicable, check the appropriate box; otherwise LEAVE blank
22	REMARKS	ENTER the name of the office or diagnostic laboratory forwarding the sample; include a contact name, email address, phone number of the contact; also include the date forwarded to the State diagnostic laboratory or USDA–APHIS–NIS
23	TENTATIVE DETERMINATION	ENTER the preliminary diagnosis
24	DETERMINATION AND NOTES (**Not** for Field Use)	LEAVE blank; will be completed by the official identifier

PPQ 523 Emergency Action Notification

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information is 0579-0102. The time required to complete this information collection is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

FORM APPROVED - OMB NO. 0579-0102

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

EMERGENCY ACTION NOTIFICATION

SERIAL NO.

1. PPQ LOCATION

2. DATE ISSUED

3. NAME AND QUANTITY OF ARTICLE(S)

4. LOCATION OF ARTICLES

5. DESTINATION OF ARTICLES

6. SHIPPER

7. NAME OF CARRIER

8. SHIPMENT ID NO.(S)

9. OWNER/CONSIGNEE OF ARTICLES

Name:

Address:

PHONE NO.

FAX NO.

SS NO.

TAX ID NO.

10. PORT OF LADING

11. DATE OF ARRIVAL

12. ID OF PEST(S), NOXIOUS WEEDS, OR ARTICLE(S)

12a. PEST ID NO.

12b. DATE INTERCEPTED

13. COUNTRY OF ORIGIN

14. GROWER NO.

15. FOREIGN CERTIFICATE NO.

15a. PLACE ISSUED

15b. DATE

Under Sections 411, 412, and 414 of the Plant Protection Act (7 USC 7711, 7712, and 7714) and Sections 10404 through 10407 of the Animal Health Protection Act (7 USC 8303 through 8306), you are hereby notified, as owner or agent of the owner of said carrier, premises, and/or articles, to apply remedial measures for the pest(s), noxious weeds, and or article(s) specified in Item 12, in a manner satisfactory to and under the supervision of an Agriculture Officer. Remedial measures shall be in accordance with the action specified in Item 16 and shall be completed within the time specified in Item 17.

AFTER RECEIPT OF THIS NOTIFICATION, ARTICLES AND/OR CARRIERS HEREIN DESIGNATED MUST NOT BE MOVED EXCEPT AS DIRECTED BY AN AGRICULTURE OFFICER. THE LOCAL OFFICER MAY BE CONTACTED AT:

16. ACTION REQUIRED

☐ TREATMENT:

☐ RE-EXPORTATION:

☐ DESTRUCTION:

☐ OTHER:

Should the owner or owner's agent fail to comply with this order within the time specified below, USDA is authorized to recover from the owner or agent cost of any care, handling, application of remedial measures, disposal, or other action incurred in connection with the remedial action, destruction, or removal.

17. AFTER RECEIPT OF THIS NOTIFICATION COMPLETE SPECIFIED ACTION WITHIN (Specify No. Hours or No. Days):

18. SIGNATURE OF OFFICER:

ACKNOWLEDGMENT OF RECEIPT OF EMERGENCY ACTION NOTIFICATION

I hereby acknowledge receipt of the foregoing notification.

SIGNATURE AND TITLE:

DATE AND TIME:

19. REVOCATION OF NOTIFICATION

ACTION TAKEN:

SIGNATURE OF OFFICER:

DATE:

PPQ FORM 523 (JULY 2002) Previous editions are obsolete.

Figure B-3 Example of PPQ 523 Emergency Action Notification

Purpose

Issue a PPQ 523, Emergency Action Notification (EAN), to hold all host plant material at facilities that have the suspected plant material directly or indirectly connected to positive confirmations. Once an investigation determines the plant material is not infested, or testing determines there is no risk, the material may be released and the release documented on the EAN.

The EAN may also be issued to hold plant material in fields pending positive identification of suspect samples. When a decision to destroy plants is made, or in the case of submitted samples, once positive confirmation is received, the same EAN which placed plants on hold also is used to document any actions taken, such as destruction and disinfection. More action may be warranted in the case of other fields testing positive for this pest.

Instructions

If plant lots or shipments are held as separate units, issue separate EAN's for each unit of suspected plant material and associated material held. EAN's are issued under the authority of the Plant Protection Act of 2000 (statute 7 USC 7701-7758). States are advised to issue their own hold orders parallel to the EAN to ensure that plant material cannot move intrastate.

When using EAN's to hold articles, it is most important that the EAN language clearly specify actions to be taken. An EAN issued for positive testing and positive-associated plant material must clearly state that the material must be disposed of, or destroyed, and areas disinfected. Include language that these actions will take place at the owner's expense and will be supervised by a regulatory official. If the EAN is used to issue a hold order for further investigations and testing of potentially infested material, then document on the same EAN, any disposal, destruction, and disinfection orders resulting from investigations or testing.

Find more instructions for completing, using, and distributing this form in the PPQ *Manual for Agricultural Clearance*.

Appendix

C

How to Submit Insect Specimens

Contents

Insects and Mites

Taxonomic support for insect surveys requires that samples be competently and consistently sorted, stored, screened in most cases, and submitted to the identifier. The following are submission requirements for insects.

1. Sorting Trap Samples

   Trapping initiative is most commonly associated with a pest survey program, such as Wood Boring and Bark Beetles (WBBB), see Bark Beetle Submission Protocol from the PPQ Eastern Region CAPS program for detailed procedures. As such, it is important to sort out the debris and non-target insect orders from the trap material. The taxonomic level of sorting will depend on the expertise available on hand and can be confirmed with the identifier.

2. Screening Trap Samples

   Consult the screening aids on the CAPS website for screening aids for particular groups. The use of these aids should be coupled with training from identifiers and/or experienced screeners before their use. These can be found at: http://pest.ceris.purdue.edu/caps/screening.php

3. Storing Samples

   Where appropriate, samples can be stored indefinitely in alcohol, however samples of dried insects such as those in sticky traps may decompose over time if not kept in a cool location such as a refrigerator or freezer. If insect samples have decomposed, do not submit them for identification.

4. Packaging and Shipping

Ensure specimens are dead before shipping. This can be accomplished by placing them in a vial of alcohol or putting the dry specimens in the freezer for at least 1day. The following are a few tips on sorting, packaging and shipping liquids, sticky traps and dry samples.

Liquids

Factors such as arthropod group, their life-stage and the means they were collected determine the way the specimens are handled, preserved and shipped to the identifier. In general mites, insect larvae, soft-bodied and hard-bodied adult insects can be transferred to vials of 75-90 percent Ethanol (ETOH), or an equivalent such as isopropyl alcohol. At times, Lingren funnel trap samples may have rainwater in them. To prevent later decay, drain off all the liquid and replace with alcohol. Vials used to ship samples should contain samples from a single trap and a printed or hand-written label with the associated collection number that is also found in the top right corner of form 391. Please make sure to use a writing utensil that isn't alcohol soluble, such as a micron pen or a pencil. It is important not to mix samples from multiple traps in a single vial so as to preserve the locality association data. Vials can be returned to field personnel upon request.

If sending specimens in alcohol is an issue with the mail or freight forwarder, most of the liquid can be decanted off from the vial and then sealed tightly in the container just before shipping. Tell the identifier that the vials will need to have alcohol added back to them as soon as they are received. During the brief time of shipping, the specimens should not dry out if the vial is properly sealed.

Sticky Trap Samples

Adult Lepidoptera, because of their fragile appendages, scales on wings, etc. require special handling and shipping techniques. Lepidoptera specimens in traps should not be manipulated or removed for preliminary screening unless expertise is available. Traps can be folded, with stickum-glue on the inside, but only without the sticky surfaces touching, and secured loosely with a rubber band for shipping. Inserting a few styrofoam peanuts on trap surfaces without insects will cushion and prevent the two sticky surfaces from sticking during shipment to taxonomists. Also DO NOT simply fold traps flat or cover traps with transparent wrap (or other material), as this will guarantee specimens will be seriously damaged or pulled apart – making identification difficult or impossible.

An alternative to this method is to cut out the area of the trap with the suspect pest and pin it securely to the foam bottom of a tray with a lid. Make sure there is some room around the specimen for pinning and future manipulation. For larger numbers of traps, placing several foam peanuts between sticky surfaces (arranged around suspect specimens) can prevent sticky surfaces from making contact when packing multiple folded-traps for shipment. DO NOT simply fold traps flat or cover traps with transparent wrap (or other material), as this will guarantee specimens will be seriously damaged or pulled apart – making identification difficult or impossible.

Dry Specimens

Some collecting methods produce dry material that is fragile. Dry samples can be shipped in vials or glassine envelopes, such as the ones that can be purchased here: http://www.bioquip.com/Search/default.asp. As with the alcohol samples, make sure the collection label is associated with the sample at all times. This method is usually used for larger insects and its downside is the higher chance of breakage during shipping. Additionally, dry samples are often covered in debris and sometimes difficult to identify.

Be sure that the samples are adequately packed for shipment to ensure safe transit to the identifier. If a soft envelope is used, wrap it in shipping bubble sheets; if a rigid cardboard box is used, pack it in such a way that the samples are restricted from moving in the container. Please include the accompanying documentation and tell the identifier before shipping. Remember to tell the identifier that samples are on the way, giving the approximate number and to include your contact information.

Documentation

Each trap sample/vial should have accompanying documentation along with it in the form of a completed PPQ form 391, Specimens for Determination. The form is fillable electronically and can be found here:

http://cals-cf.calsnet.arizona.edu/azpdn/labs/submission/PPQ_Form_391.pdf

It is good practice to keep a partially filled electronic copy of this form on your computer with your address and other information filled out in the interest of saving time. Indicate the name of the person making any tentative identification before sending to an identifier. Please make sure all fields that apply are filled out and the bottom field (block 24: Determination and Notes) is left blank to be completed by the identifier. Include the trap type, lure used, and trap number on the form. Also, include the phone number and/or e-mail address of the submitter. Other documentation in the form of notes, images, etc. can be sent along with this if it useful to the determination. It is important that there be a way to cross-reference the sample/vial with the accompanying form. This can be done with a label with the “Collection Number” in the vial or written on the envelope, etc.

Appendix

D Taxonomic Support for Surveys

Contents

Background

The National Identification Services (NIS) coordinates the identification of plant pests in support of USDA's regulatory programs. Accurate and timely identifications are the foundation of quarantine action decisions and are essential in the effort to safeguard the nation's agricultural and natural resources.

NIS employs and collaborates with scientists who specialize in various plant pest groups, including weeds, insects, mites, mollusks and plant diseases. These scientists are stationed at a variety of institutions around the country, including federal research laboratories, plant inspection stations, land-grant universities, and natural history museums. Additionally, the NIS Molecular Diagnostics Laboratory is responsible for providing biochemical testing services in support of the agency's pest monitoring programs.

On June 13, 2007, the PPQ Deputy Administrator issued PPQ Policy No. PPQ-DA-2007-02 which established the role of PPQ NIS as the point of contact for all domestically- detected, introduced plant pest confirmations and communications. A Domestic Diagnostics Coordinator (DDS) position was established to administer the policy and coordinate domestic diagnostic needs for NIS. This position was filled in October of 2007 by Joel Floyd (USDA, APHIS, PPQ-PSPI,NIS 4700 River Rd., Unit 52, Riverdale, MD 20737, phone (301) 734-4396, fax (301) 734-5276, e-mail: joel.p.floyd@aphis.usda.gov).

Taxonomic Support and Survey Activity

Taxonomic support for pest surveillance is basic to conducting quality surveys. A misidentification or incorrectly screened target pest can mean a missed opportunity for early detection when control strategies would be more viable and cost effective. The importance of good sorting, screening, and identifications in our domestic survey activity cannot be overemphasized.

Fortunately most states have, or have access to, good taxonomic support within their states. Taxonomic support should be accounted for in cooperative agreements as another cost of conducting surveys. Taxonomists and laboratories within the State often may require supplies, develop training materials, or need to hire technicians to meet the needs of screening and identification. As well, when considering whether to survey for a particular pest a given year, consider the challenges of taxonomic support.

Sorting and Screening

For survey activity, samples that are properly sorted and screened before being examined by an identifier will result in quicker turn around times for identification.

Sorting

Sorting is the first level of activity that assures samples submitted are of the correct target group of pests being surveyed, that is, after removal of debris, ensure that the correct order, or in some cases family, of insects is submitted; or for plant disease survey samples, select those that are symptomatic if appropriate. There should be a minimum level of sorting expected of surveyors depending on the target group, training, experience, or demonstrated ability.

Screening

Screening is a higher level of discrimination of samples such that the suspect target pests are separated from the known non-target, or native species of similar taxa. For example, only the suspect target species or those that appear similar to the target species are forwarded to an identifier for confirmation. There can be first level screening and second level depending on the difficulty and complexity of the group. Again, the degree of screening appropriate is dependent on the target group, training, experience, and demonstrated ability of the screener.

Check individual survey protocols to determine if samples should be sorted, screened or sent entire (raw) before submitting for identification. If not specified in the protocol, assume that samples should be sorted at some level.

Resources for Sorting, Screening, and Identification

Sorting, screening, and identification resources and aids useful to CAPS and PPQ surveys are best developed by taxonomists who are knowledgeable of the taxa that includes the target pests and the established or native organisms in the same group that are likely to be in samples and can be confused with the target. Many times these aids can be regionally based. They can be in the form of dichotomous keys, picture guides, or reference collections. NIS encourages the development of these resources, and when aids are complete, post them in the CAPS Web site so others can benefit. If local screening aids are developed, please notify Joel Floyd, the Domestic Diagnostics Coordinator, as to their availability. Please see the following for some screening aids available: http://pest.ceris.purdue.edu/caps/screening.php

Other Entities for Taxonomic Assistance in Surveys

When taxonomic support within a state is not adequate for a particular survey, in some cases other entities may assist including PPQ identifiers, universities and state departments of agriculture in other states, and independent institutions. Check with the PPQ regional CAPS coordinators about the availability of taxonomic assistance.

Universities and State Departments of Agriculture

Depending on the taxonomic group, there are a few cases where these two entities are interested in receiving samples from other states. Arrangements for payment, if required for these taxonomic services, can be made through cooperative agreements. The National Plant Diagnostic Network (NPDN) also has five hubs that can provide service identifications of plant diseases in their respective regions.

Independent Institutions

The Eastern Region PPQ office has set up multi-state arrangements for Carnegie Museum of Natural History to identify insects from trap samples. They prefer to receive unscreened material and work on a fee basis per sample.

PPQ Port Identifiers

There are over 70 identifiers in PPQ that are stationed at ports of entry who primarily identify pests encountered in international commerce including conveyances, imported cargo, passenger baggage, and propagative material. In some cases, these identifiers process survey samples generated in PPQ conducted surveys, and occasionally from CAPS surveys. They can also enter into our Pest ID database the PPQ form 391 for suspect CAPS target or other suspect new pests, prior to being forwarded for confirmation by an NIS recognized authority.

PPQ Domestic Identifiers

PPQ also has a limited number of domestic identifiers (three entomologists and two plant pathologists) normally stationed at universities who are primarily responsible for survey samples. Domestic identifiers can be used to handle unscreened, or partially screened samples, with prior arrangement through the PPQ regional survey coordinator. They can also as an intermediary alternative to sending an unknown suspect to, for example, the ARS Systematic Entomology Lab (SEL), depending on their specialty and area of coverage.

They can also enter into our Pest ID database the PPQ form 391 for suspect CAPS target or other suspect new pests, prior to being forwarded for confirmation by an NIS recognized authority.

PPQ Domestic Identifiers
Bobby Brown
Domestic Entomology Identifier
Specialty: forest pests (coleopteran, hymenoptera)
Area of coverage: primarily Eastern Region

USDA, APHIS, PPQ
901 W. State Street
Smith Hall, Purdue University
Lafayette, IN 47907-2089
Phone: 765-496-9673
Fax: 765-494-0420
e-mail: robert.c.brown@aphis.usda.gov

Julieta Brambila
Domestic Entomology Identifier
Specialty: adult Lepidoptera, Hemiptera
Area of Coverage: primarily Eastern Region
USDA APHIS PPQ
P.O. Box 147100
Gainesville, FL 32614-7100
Office phone: 352- 372-3505 ext. 438, 182
Fax: 352-334-1729
e-mail: julieta.bramila@aphis.usda.gov

Kira Zhaurova
Domestic Entomology Identifier
Specialty: to be determine
Area of Coverage: primarily Western Region
USDA, APHIS, PPQ
Minnie Belle Heep 216D
2475 TAMU
College Station, TX 77843
Phone: 979-450-5492
e-mail: kira.zhaurova@aphis.usda.gov

Grace O'Keefe
Domestic Plant Pathology Identifier
Specialty: Molecular diagnostics (citrus greening, P. ramorum, bacteriology, cyst nematode screening)
Area of Coverage: primarily Eastern Region

USDA, APHIS, PPQ
105 Buckhout Lab
Penn State University
University Park, PA 16802
Lab: 814 - 865 - 9896
Cell: 814 – 450- 7186
Fax: 814 - 863 – 8265
e-mail: grace.okeefe@aphis.usda.gov

Craig A. Webb, Ph.D.
Domestic Plant Pathology Identifier
Specialty: Molecular diagnostics (citrus greening, P. ramorum, cyst nematode screening)
Area of Coverage: primarily Western Region
USDA, APHIS, PPQ
Department of Plant Pathology
Kansas State University
4024 Throckmorton Plant Sciences
Manhattan, KS 66506-5502
Cell (785) 633-9117
Office (785) 532-1349
Fax: 785-532-5692
e-mail: craig.a.webb@aphis.usda.gov

Final Confirmations

If identifiers or laboratories at the state, university, or institution level suspect they have detected a CAPS target, a plant pest new to the United States, or a quarantine pest of limited distribution in a new state, the specimens should be forwarded to an NIS recognized taxonomic authority for final confirmation. State cooperator and university taxonomists can go through a PPQ area identifier or the appropriate domestic identifier that covers their area to get the specimen in the PPQ system (for those identifiers, see table G-1-1 in the Agriculture Clearance Manual, Appendix G link below). They will then send it to the NIS recognized authority for that taxonomic group.

State level taxonomists, who are reasonably sure they have a new United States. record, CAPS target, or new federal quarantine pest, can send the specimen directly to the NIS recognized authority, but must notify their State Survey Coordinator (SSC), PPQ Pest Survey Specialist (PSS), State Plant Health Director (SPHD), and State Plant Regulatory Official (SPRO).

Before forwarding these suspect specimens to identifiers or for confirmation by the NIS recognized authority, please complete a PPQ form 391 with the tentative determination. Also fax a copy of the completed PPQ Form 391 to

"Attention: Domestic Diagnostics Coordinator" at 301-734-5276, or send a PDF file in an e-mail to mailto:nis.urgents@aphis.usda.govwith the overnight carrier tracking number.

The addresses of NIS recognized authorities of where suspect specimens are to be sent can be found in The Agriculture Clearance Manual, Appendix G, tables G-1-4 and G-1-5: http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/mac_pdf/g_app_identifiers.pdf

Only use Table G-1-4, the "Urgent" listings, for suspected new United States records, or state record of a significant pest, and Table G-1-5, the "Prompt" listings, for all others.

When the specimen is being forwarded to a specialist for NIS confirmation, use an overnight carrier, insure it is properly and securely packaged, and include the hard copy of the PPQ form 391 marked "Urgent" if it is a suspect new pest, or "Prompt" as above.

Please contact Joel Floyd, the Domestic Diagnostics Coordinator if you have questions about a particular sample routing, at phone number: 301-734-5276, or e-mail: joel.p.floyd@aphis.usda.gov

Digital Images for Confirmation of Domestic Detections

For the above confirmations, do not send digital images for confirmation. Send specimens in these instances. For entry into NAPIS, digital imaging confirmations can be used for new county records for widespread pests by state taxonomists or identifiers if they approve it first. They always have the prerogative to request the specimens be sent.

Communications of Results

If no suspect CAPS target, program pests, or new detections are found, communication of these identification results can be made by domestic identifiers or taxonomists at other institutions directly back to the submitter. They can be in spread sheet form, on hard copy PPQ form 391's, or other informal means with the species found, or "no CAPS target or new suspect pest species found". Good record keeping by the intermediate taxonomists performing these identifications is essential.

All confirmations received from NIS recognized authorities, positive or negative, are communicated by NIS to the PPQ Emergency and Domestic Programs (EDP) staff in PPQ headquarters. EDP then notifies the appropriate PPQ program managers and the SPHD and SPRO simultaneously. One of these contacts should forward the results to the originating laboratory, diagnostician, or identifier.

Data Entry

Cooperative Agricultural Pest Survey (CAPS)

For survey data entered into NAPIS, new country and state records should be confirmed by an NIS recognized authority, while for others that are more widespread, use the identifications from PPQ identifiers or state taxonomists.

Appendix E

Images

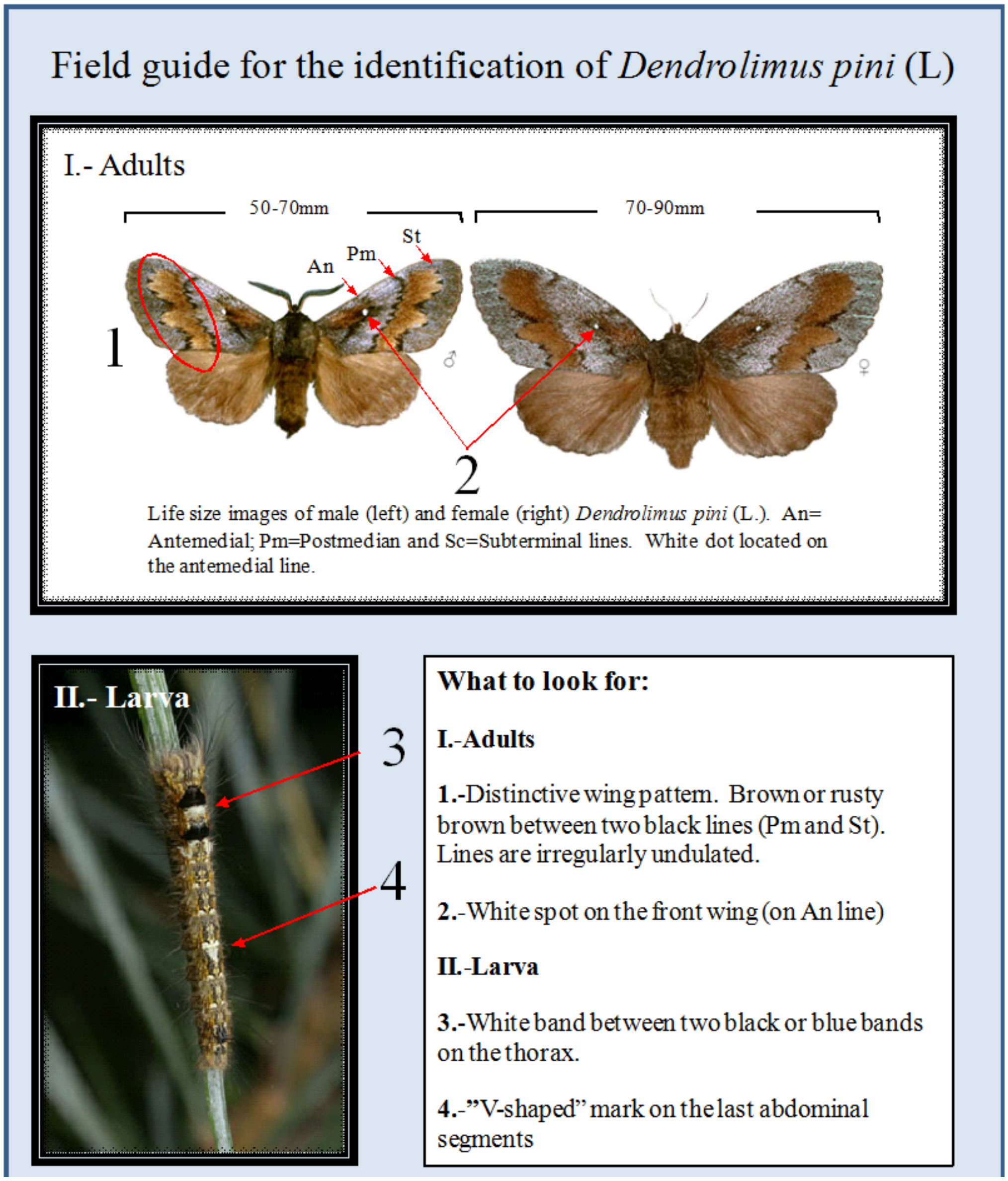

Figure E-1 Field guide for the identification of *Dendrolimus pini* (L.), the pine-tree lappet. Adult moths photograph by Peslier Serge. Larva photograph by Jeroen Voogd.

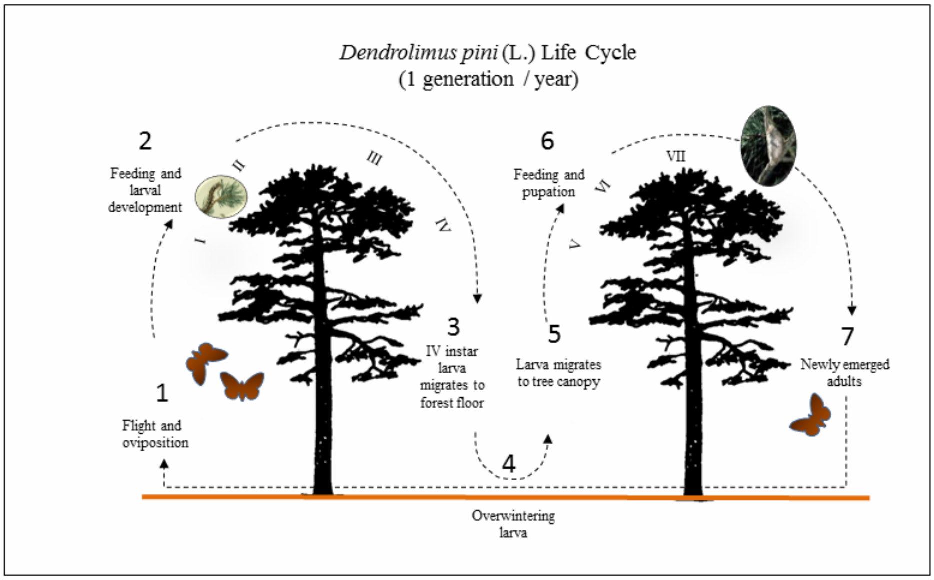

Figure E-2 Typical one generation per year life cycle of *Dendrolimus pini* (L.), pine-tree lappet. Roman numerals correspond to the larval stages. See Pest Identification section for specific pictures of each developmental stage. Silhouette picture of Scots pine by Ian Burt at http://commons.wikimedia.org/wiki/File:Pinus_sylvestris_Silhouette_(oddsock).png

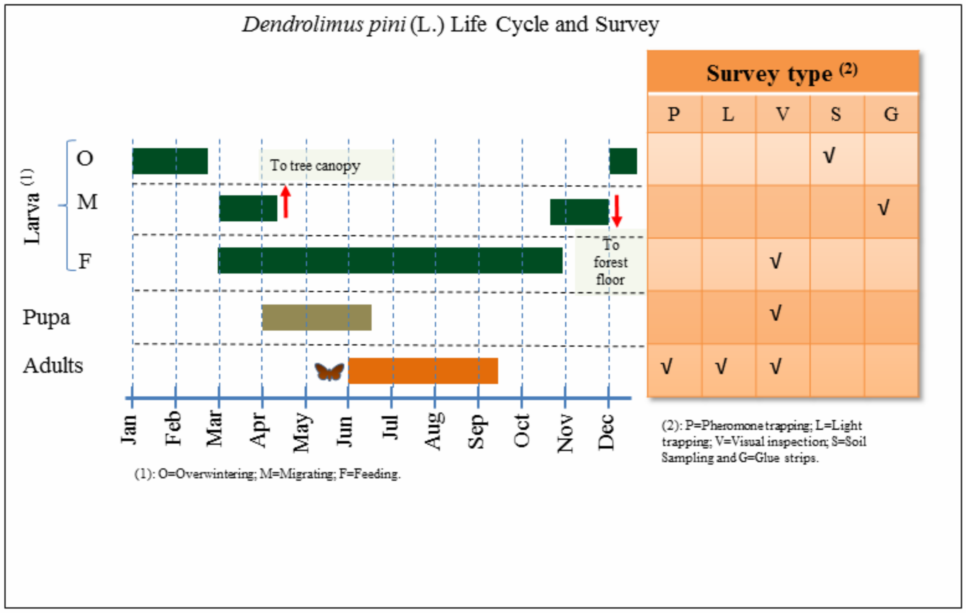

Figure E-3 ***Dendrolimus pini*** **(L.) Life Cycle and Survey. Chronological development of *Dendrolimus pini* (L.), pine-tree lappet and suggested types of survey for each specific developmental stage. During an outbreak, pesticides applications are normally done early in the spring, at the end of the overwintering period between March and May.**

Appendix

F

Biological Control

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Bacteria		
Achromobacter sp.	Larva	Sierpinska, 1998
Aerobacter aerogenes	Larva	Sierpinska, 1998
Aerobacter cloaceae	Larva	Sierpinska, 1998
Bacillus brevis	Larva	Sierpinska, 1998
Bacillus cereus	Larva	Sierpinska, 1998
Bacillus cereus var. mycoides	Larva	Sierpinska, 1998
Bacillus megaterium	Larva	Sierpinska, 1998
Bacillus thuringiensis subsp. *Sotto* biotype *dendrolimus*	Larva	Sierpinska, 1998
Klebsiella aerogenes	Larva	Sierpinska, 1998
Proteus rettgeri	Larva	Sierpinska, 1998
Pseudomonas aeruginosa	Larva	Sierpinska, 1998
Pseudomonas chlororaphis	Larva	Sierpinska, 1998
Sarcina flava	Larva	Sierpinska, 1998
Serratia marcescens	Larva	Sierpinska, 1998
Fungi		
Acremonium aranearum	Larva	Sierpinska, 1998
Aspergillus parasiticus	Larva	Sierpinska, 1998
Beauveria bassiana	Larva	Malinowski, 2009; Sierpinska, 1998
Beauveria tenella	Larva	Sierpinska, 1998
Cordyceps militaris	Larva	Sierpinska, 1998
Fusarium sp.	Larva	Sierpinska, 1998
Metarhizium anisopliae	Larva	Malinowski, 2009
Mucor sp.	Larva	Sierpinska, 1998
Paecilomyces farinosus	Larva	Malinowski, 2009; Sierpinska, 1998
Paecilomyces fumoso-roseus	Larva	Sierpinska, 1998
Penicillum sp.	Larva	Sierpinska, 1998
Scopulariopsis brevicaulis	Larva	Sierpinska, 1998
Verticillum falcatum	Larva	Sierpinska, 1998

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Verticillum lecanii	Larva	Malinowski, 2009; Sierpin-ska, 1998
Verticillum sp. I	Larva	Sierpinska, 1998
Verticillum sp. II	Larva	Sierpinska, 1998
Viruses		
Cytoplasmic Polyhedrosis Virus of D. pini	Larva	Slizynski and Lipa, 1975
Granulosis virus of Dendroli-mus sibiricus	Egg, Larva, Pupa	Orlovskaya, 1998
Insects Order: Family		
Coleoptera: Carabidae		
Calasoma sycophanta L.	Larval and pupal predator	Sierpinska, 1998; Melis, 1940
Carabus violaceus L.	Larva predator	Sierpinska, 1998
Carabus coriaceus L.	Larva predator	Sierpinska, 1998
Diptera: Muscidae		
Amphiochaeta rufipes Meig	Larval parasitoid	Sierpinska, 1998;Sitowski, 1928
Muscina pabulorum Fallen	Larval parasitoid	Sierpinska, 1998; Melis, 1940
Muscina stabulans Fallen	Larval parasitoid	Sierpinska, 1998; Sitowski, 1928
Stomoxys calcitrans L.	Larval parasitoid	Sierpinska, 1998;Sitowski, 1928
Diptera: Sarcophagidae		
Agria affinis (Fallen)	Larval parasitoid	Melis, 1940; Sitowski, 1928
Parasarcophaga harpax Pandellé	Larval and pupal parasitoid	Sierpinska, 1998; Malyshev, 1996
Parasarcophaga portschin-skyi Rohdendorf	Pupal parasitoid	Malyshev, 1996
Pseudosarcophaga affinis (Fallen)	Pupal parasitoid	Malyshev, 1996
Sarcophaga albiceps Mei-gen	Larval parasitoid	Matsumura, 1926a; Melis, 1940
Sarcophaga schuetzei Kramer	Larval parasitoid	Melis, 1940

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Sarcophaga tuberosa Pandellé	Larval parasitoid	Sierpinska, 1998; Melis, 1940
Sarcophaga uliginosa Kramer	Larval parasitoid	Melis, 1940
Diptera: Tachinidae		
Campylochaeta inepta (Meigen)	Larval parasitoid	Ford and Shaw, 2010
Compsilura concinnata (Meigen)	Larval parasitoid Parasitoid	Malyshev, 1996 Melis, 1940
Blepharipa pratensis (Meigen)	Larval and pupal parasitoid	Malyshev, 1996;Ford and Shaw, 2010
Blondelia nigripes (Fallen)	Larval and pupal parasitoid	Malyshev, 1996
Drino atropivora (Robineau-Desvoidy)	Larval and pupal parasitoid	Malyshev, 1996
Drino inconspicua (Meigen)	Larval and pupal parasitoid	Malyshev, 1996
Exorista affinis Fallen	Larval and pupal parasitoid	Malyshev, 1996
Exorista larvarum L.	Larval and pupal parasitoid	Malyshev, 1996 Melis, 1940
Lydella nigripes Fallen	Larval and pupal parasitoid	Melis, 1940
Masicera cuculliae Robineau-Desvoidy	Larval and pupal parasitoid	Malyshev, 1996
Nowickia ferox (Panzer)	Larval and pupal parasitoid	Malyshev, 1996
Pales pavida (Meigen)	Larval and pupal parasitoid	Melis, 1940
Parasetigena silvestris (Robineau-Desvoidy)	Larval and pupal parasitoid	Malyshev, 1996
Phryxe vulgaris Fallen	Larval and pupal parasitoid	Melis, 1940
Sturmia bimaculata Hartig	Larval and pupal parasitoid	Melis, 1940
Hymenoptera: Braconidae		
Apanteles liparidis	Larval parasitoid	Malyshev, 1996
Meteorus versicolor Wesmael	Larval parasitoid	Sierpinska, 1998; Malyshev, 1996
Meteorus bimaculatus Wesmael.	Larval parasitoid	Melis, 1940
Microgaster memorum Ratzeburg	Larval parasitoid	Melis, 1940
Microgaster gastropachae Bouché	Larval parasitoid	Melis, 1940
Microgaster glomeratus Brischke	Larval parasitoid	Melis, 1940
Microgaster ordinarius Brischke	Larval parasitoid	Melis, 1940
Perilitus secalis Haliday	Larval parasitoid	Melis, 1940

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Perilitus bicolor Wesmael	Larval parasitoid	Melis, 1940
Perilitus unicolor Ratzeburg	Larval parasitoid	Melis, 1940
Rhogas esenbeckii Ratzeburg	Larval parasitoid	Melis, 1940
Hymenoptera: Chalcididae		
Anastatus bifasciatus (Fonscolombe)	Egg parasitoid	Melis, 1940
Chrysolampus solitarius Hartig	Egg parasitoid	Melis, 1940
Encyrtus chalconotus Brischke	Egg parasitoid	Melis, 1940
Encyrtus embryophagus Hartig	Egg parasitoid	Melis, 1940
Entendon evanescens Ratzeburg	Egg parasitoid	Melis, 1940
Entendon xanthopus Nees.	Egg parasitoid	Melis, 1940
Eurytoma abrotani Ratzeburg	Egg parasitoid	Melis, 1940
Monodontomerus aureus Walker	Egg parasitoid	Melis, 1940
Monodontomerus minor Brischke	Egg parasitoid	Melis, 1940
Pentarthron carpocapsae Schreiner	Egg parasitoid	Melis, 1940
Pteromalum muscarum Ratzeburg	Egg parasitoid	Melis, 1940
Pteromalum eucerum Brischke	Egg parasitoid	Melis, 1940
Tetrastichus xanthopus Nees	Egg parasitoid	Melis, 1940
Torymus anephelus Ratzeburg	Egg parasitoid	Melis, 1940
Torymus minor Ratzeburg	Egg parasitoid	Melis, 1940
Hymenoptera: Formicidae		
Formica polyctena Forster	Larval predator	Sierpinska, 1998
Formica nigricans Emery	Larval predator	Malysheva, 1963
Formica rufa L.	Larval predator	Sierpinska, 1998
Hymenoptera: Ichneumonidae		
Anomalon giganteum Ratzeburg		Melis, 1940
Anomalon unicolor Ratzeburg		Melis, 1940

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Aphanistes bigutattus Grav		Melis, 1940
Blaptocampus nigricornis Wesmael		Melis, 1940
Ephialtes mediator Ratzeburg		Melis, 1940
Exochilum circumflexum L.		Melis, 1940
Habronyx heros Wesmael		Melis, 1940
Hemiteles brunnipes Ratzeburg		Melis, 1940
Hemiteles fulvipes Gravenhorst		Matsumura, 1926a
Hemiteles areator Ratzeburg		Melis, 1940
Ichneumon fusorius L.		Melis, 1940
Ichneumon ratzeburgii Ratzeburg		Melis, 1940
Ischchnoceros marchicus Ratzeburg		Melis, 1940
Iseropus stercorator (Fabricius)	Larval and Pupal parasitoid	Malyshev, 1996
Mesochorus ater Ratzeburg		Melis, 1940
Ophion luteus Ratzeburg		Melis, 1940
Ophion obscurus Ratzeburg		Melis, 1940
Paniscus testaceus Ratzeburg		Melis, 1940
Pezomachus agilis Ratzeburg		Melis, 1940
Pezomachus cursitans Ratzeburg		Melis, 1940
Pezomachus latrator Ratzeburg		Melis, 1940
Pezomachus pedestris Ratzeburg		Melis, 1940
Pimpla bernuthii Brischke		Melis, 1940; Matsumura, 1926a
Pimpla didyma Grav		Melis, 1940
Pimpla flaconotata Brischke		Melis, 1940
Pimpla favicans Ratzeburg		Melis, 1940
Pimpla holmgreni Schmiedeknecht	Larval parasitoid	Sierpinska, 1998; Melis, 1940
Pimpla instigator Fabricius	Larval and pupal parasitoid	Sierpinska, 1998; Melis, 1940
Pimpla musii Ratzeburg		Melis, 1940

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Pimpla turionella Ratzeburg		Melis, 1940
Trogus lutorius Ratzeburg		Melis, 1940
Hymenoptera: Scelionidae		
Telenomus laeviusculus (Ratzeburg)	Egg parasitoid	Moeller and Engelmann, 2008
Telenomus verticillatus Kiefer	Egg parasitoid	Sierpinska, 1998; Ruivkin, 1950
Telenomus phalaenarum Nees	Egg parasitoid	Melis, 1940
Telenomus tetratomus Kief-fer	Egg parasitoid	Malyshev, 1996
Hymenoptera: Tetrastichi-dae		
Tetrastichus xanthops (Rat-zeburg)	Larval/Pupal parasitoid	Malyshev, 1996
Hymenoptera: Trichogram-matidae		
Trichogramma cocoeciae Marchal	Egg parasitoid	Malyshev, 1996, 1996
Trichogramma embryoph-agum Hartig	Egg parasitoid	Malyshev, 1996 1996; Sier-pinska, 1998
Trichogramma evanescens Westwood	Egg parasitoid	Malyshev, 1996
Raphidoptera: Raphidae		
Rhaphidia ophiopsis L.	Egg and larval predator	Sierpinska, 1998
Rhynchota: Pentatomidae		
Picromerus bidens L.	Larva predator	Sierpinska, 1998
Troilus luridus L.	Larva predator	Sierpinska, 1998
Birds and Mammals		
Cuckoo (Cuculidae)	Larval and adult predator	Sierpinska, 1998
Golden orioles (*Oriolus orio-lus*)	Larval and adult predator	Sierpinska, 1998
Starlings (*Stumus vulgaris*)	Larval and adult predator	Sierpinska, 1998
Coal-tits (*Periparus sp.*)	Larval and adult predator	Sierpinska, 1998
Jays (*Cyanocitta sp.*)	Larval and adult predator	Sierpinska, 1998
Thrushs (Turdidae)	Larval and adult predator	Sierpinska, 1998
Rooks (*Corvus frugilegus*)	Larval and adult predator	Sierpinska, 1998

Table F-1 Reported potential biological control agents of Pine Tree Lappet, *Dendrolimus pini* (L.)

Organism group Species	Host stage affected	References
Jackdaws (*Corvus monedula*)	Larval and adult predator	Sierpinska, 1998
Chaffinchs (*Fringilla coelebs*)	Larval and adult predator	Sierpinska, 1998
Woodpeckers	Larval and adult predator	Sierpinska, 1998
Moles	Hybernating larva predator	Sierpinska, 1998
Bats	Adults predator	Sierpinska, 1998

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
INSECTS Order: Family				
Diptera: Bombyliidae				
Hemipenthes maurus L.	Larval parasitoid	Yes		Kolomiec, 1962
Diptera: Chalcididae				
Brachymeria minuta L.	Larval parasitoid	Yes		Kolomiec, 1962
Diptera: Heleidae				
Forcypomia sp.		Yes		Kolomiec, 1962
Diptera: Muscidae				
Muscina stabulans Fallen	Larval parasitoid	Yes		Kolomiec, 1962
Muscina assimilis Fallen	Larval parasitoid	Yes		Kolomiec, 1962
Diptera: Sarcophagidae				
Sarcophaga albiceps Meigen	Predacious	Yes	Yes	Matsumura, 1926a, 1926b
Diptera: Tachinidae				
Blepharipa schineri (Mesnil)	Larval parasitoid	Yes		Kolomiec, 1962
Blepharipa scutellata (Robineau-Desvoidy)	Larval parasitoid	Yes		Kolomiec, 1962
Blepharipa pratensis (Meigen)	Larval parasitoid	Yes		Kolomiec, 1962
Carcelia excisa Fallen	Larval-pupal parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Carcelia gnava Meigen	Larval-pupal parasitoid		Yes	Matsumura, 1926a

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Ctenophorocera pavida (Meigen)	Larval-pupal parasitoid	Yes		Kolomiec, 1962
Echinomyia dendrolimi Matsumura	Larval-pupal parasitoid	Yes		Matsumura, 1926b
Echinomyia dendrolimusi Matsumura	Larval-pupal parasitoid		Yes	Matsumura, 1926a
Exorista fasciata Fallen	Larval parasitoid	Yes		Kolomiec, 1962; Yue et al., 1996
Exorista larvarum (L.)	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Tachina grossa L.	Larval parasitoid	Yes		Kolomiec, 1962
Hubneria affinis (Fallen)	Larval parasitoid	Yes		Kolomiec, 1962
Kramerea schutzei Kramer	Larval parasitoid	Yes		Kolomiec, 1962
Masicera sphingivora (Robineau-Desvoidy)	Larval parasitoid	Yes		Kolomiec, 1962
Masicera zimini Kolomiets	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Nemosturmia amoena (Meigen)	Larval-pupal parasitoid	Yes		Yue et al., 1996
Pales pavida Meigen	Larval parasitoid	Yes		CABI, 2011a
Parasarcophaga albiceps Meigen	Larval parasitoid	Yes		Kolomiec, 1962
Parasarcophaga harpax Pand	Larval parasitoid	Yes		Kolomiec, 1962
Parasarcophaga pseudoscoparia (Kramer)	Larval parasitoid	Yes		Kolomiec, 1962
Parasarcophaga uliginosa Kramer	Larval parasitoid	Yes		Kolomiec, 1962
Pseudosarcophaga affinis (Fall)	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Hemiptera: Pentatomidae				
Picromerus bidens L.	Larval Predator	Yes	Yes	Kolomiec, 1962
Picromerus lewisi Scott	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Zicrona coerulea L.	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Hemiptera: Reduvidae				
Harpactor leucospilus Stal	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Nabis kurilensis Matsumura	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Coleoptera: Carabidae				
Calosoma chinensis Kirby	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Calosoma ogumae Matsumura	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Calosoma maximowiczi Mor.	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Hymenoptera: Braconidae				
Apanteles dendrolimi Matsumura	Larval parasitoid	Yes		Matsumura, 1926b
Apanteles dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Apanteles eucosmae Wilkinson	Larval parasitoid	Yes		Liu and Shih, 1957
Apanteles liparidis Bouche	Larval parasitoid	Yes	Yes	Fukuyama, 1980; Kasparyan, 1965; Kolomiec, 1962
Apanteles ordinarius (Ratzeburg)	Larval parasitoid	Yes	Yes	Fukuyama, 1980; Kolomiec, 1962; Liu and Shih, 1957; Tabata and Tamanuki, 1940; Yue et al., 1996
Apanteles rubripes (Haliday)	Larval parasitoid	Yes		Kolomiec, 1962
Cotesia ordinaria (Ratzeburg)	Larval parasitoid	Yes		Kolomiec, 1962
Phanomerus dendrolimi Matsumura	Larval parasitoid	Yes		Matsumura, 1926b
Phanomeris dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Rhogas dendrolimi (Matsumura)	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962; Tabata and Tamanuki, 1940
Rhogas spectabilis (Matsumura)	Larval parasitoid	Yes		Liu and Shih, 1957
Hymenoptera: Callimomidae				
Monodontomerus minor (Ratzeburg)	Pupal parasitoid	Yes		Kolomiec, 1962
Monodontomerus obsoletus Fabricius	Pupal parasitoid	Yes		Kolomiec, 1962

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Hymenoptera: Encyrtidae				
Encyrtus pinicola Matsumura	Egg parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Ooencyrtus pinicolus (Matsumura)	Egg parasitoid	Yes		Kolomiec, 1962; Yao et al., 2005
Ooencyrtus sp.	Egg parasitoid	Yes		Yue et al., 1996
Ooencyrtus dendrolimusi Chu	Egg parasitoid	Yes		Liu and Shih, 1957
Ooencyrtus pinicolus (Matsumura)	Egg parasitoid		Yes	Tabata and Tamanuki, 1940
Hymenoptera: Eupelmidae				
Anastatus disparis Ruschka	Egg parasitoid	Yes		Kolomiec, 1962
Eupelmella vesicularis (Retzius)	Larval parasitoid	Yes		Kolomiec, 1962
Eupelmus microzonus Forster	Larval parasitoid	Yes		Kolomiec, 1962
Hymenoptera: Eurtomidae				
Eurytoma sp.	Larval parasitoid	Yes		Kolomiec, 1962
Hymenoptera: Formicidae				
Formica rufa L.	Larval predator	Yes		Kolomiec, 1962
Hymenoptera: Ichneumonidae				
Amblyteles amatorius (Muller)	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b; Tabata and Tamanuki, 1940
Anilasta valida Pfank	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Apechthis compunctor (L.)	Larval parasitoid	Yes		Kolomiec, 1962
Apechthis dendrolimi (Matsumura)	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Astiphromma strenuum (Holmgren)	Larval parasitoid	Yes		Kolomiec, 1962
Campoplex proximus Foster	Larval parasitoid	Yes		Liu and Shih, 1957
Campoplex sp	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Casinaria nigripes (Gravenhorst)	Larval parasitoid	Yes		Kolomiec, 1962; Yue et al., 1996
Coccygomimus instigator (Fabricius)	Pupal parasitoid	Yes		Yue et al., 1996
Cratocryptus opacus Thompson	Larval parasitoid	Yes		Kolomiec, 1962

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Delomerista mandibularis Gravenhorst	Pupal parasitoid	Yes		Kolomiec, 1962
Epiurus sp			Yes	Tabata and Tamanuki, 1940
Exochilum circumflexum (L.)	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Exochilum dendrolimi Matsumura	Larval parasitoid	Yes		Matsumura, 1926b
Exochilum dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Exochilum giganteum Gravenhorst	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Exochilum laricis Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Exochilum sachalinense Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Exolytus splendens (Gravenhorst)	Larval parasitoid	Yes		Kolomiec, 1962
Gelis spp.	Larval parasitoid	Yes		Kolomiec, 1962
Habronyx gigas Kriechbaumer	Larval-pupal parasitoid	Yes		Kolomiec, 1962
Habronyx heros (Kriechbaumer.)	Larval parasitoid		Yes	Fukuyama, 1980; Kasparyan, 1965; Tabata and Tamanuki, 1940; Yue et al., 1996
Habronyx matsukemushii Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926b
Habronyx jozankeanus Matsumura	Larval parasitoid		Yes	Matsumura, 1926a, 1926b
Hemiteles sp	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Hemiteles dendrolimi Matsumura	Larval parasitoid	Yes		Matsumura, 1926b
Hemiteles dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Hyposoter sp.	Larval parasitoid		Yes	Fukuyama, 1980
Hyposoter takagii (Matsumura)	Larval parasitoid	Yes		Yue et al., 1996
Iseropus stercorator (Fabricius)	Pupal parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Itoplectis alternans (Gravenhorst)	Pupal parasitoid	Yes		Kolomiec, 1962
Mesochorus sp.	Larval parasitoid	Yes		Kolomiec, 1962

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Mesochorus kuwayamae Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b; Tabata and Tamanuki, 1940
Mesostemus matsukemushii Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Opheltes apicalis Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926b
Opheltes glaucopterus L.	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Paniscus testaceus Gravenhorst			Yes	Tabata and Tamanuki, 1940
Pezomachus dendrolimi Matsumura	Larval parasitoid	Yes		Matsumura, 1926b
Pezomachus dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Phygadeuon canaliculatus Thompson	Larval parasitoid	Yes		Kolomiec, 1962
Phygadeuon sp.	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Pimpla disparis Viereck	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Pimpla instigator (Fabricius)	Pupal parasitoid	Yes	Yes	Kolomiec, 1962; Tabata and Tamanuki, 1940
Pimpla jezoensis Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Pimpla pluto Ashmead	Pupal parasitoid		Yes	Tabata and Tamanuki, 1940
Pimpla tabatai Uchida	Pupal parasitoid		Yes	Tabata and Tamanuki, 1940
Pimpla turionellae L.	Pupal parasitoid	Yes	Yes	Kolomiec, 1962; Tabata and Tamanuki, 1940
Spilichneumon oratorius (Fabricius)	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b; Tabata and Tamanuki, 1940
Schizoloma amictum (Fabricius)	Larval parasitoid		Yes	Tabata and Tamanuki, 1940
Stylocryptus profligator (Fabricius)			Yes	Tabata and Tamanuki, 1940

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Theronia atalantae Poda	Larval parasitoid	Yes	Yes	Fukuyama, 1980; Kasparyan, 1965; Kolomiec, 1962; Tabata and Tamanuki, 1940
Theronia japonica Ashmead	Larval parasitoid	Yes		Matsumura, 1926b
Hymenoptera: Perilampidae				
Perilampus nitens Walker	Larval parasitoid	Yes		Kolomiec, 1962
Hymenoptera: Pteromalidae				
Dibrachys cavus (Walker)	Larval parasitoid	Yes		Kolomiec, 1962
Eutelus matsukemushii Matsumura	Larval parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962
Habrocytus sp.	Larval parasitoid	Yes		Kolomiec, 1962
Holcaerus dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Hypopteromalus apantelophagus (Crawford)			Yes	Tabata and Tamanuki, 1940
Mesopolobus superansi Yang & Gu	Egg parasitoid	Yes		Yao et al., 2005
Pachyneuron nawai Ashmead	Egg parasitoid	Yes	Yes	Liu and Shih, 1957; Tabata and Tamanuki, 1940
Pachyneuron solitarium (Hartig)	Larval parasitoid	Yes	Yes	Kolomiec, 1962; Yao et al., 2005; Yue et al., 1996
Pteromalus sp.	Larval parasitoid	Yes		Kolomiec, 1962
Pteromalus dendrolimi Matsumura	Larval parasitoid	Yes		Matsumura, 1926b
Pteromalus dendrolimusi Matsumura	Larval parasitoid		Yes	Matsumura, 1926a
Pteromalus matsukemushii Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Pteromalus matsuyadorii Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Pteromalus kuwayamae Matsumura	Larval parasitoid	Yes	Yes	Matsumura, 1926a, 1926b
Hymenoptera: Scelionidae				
Telenomus gracilis (Mayr)	Egg parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Telenomus tetratomus Kieffer	Egg parasitoid	Yes	Yes	Kolomiec, 1962; Yao et al., 2005; Yue et al., 1996
Telenomus dendrolimusi Matsumura	Egg parasitoid	Yes	Yes	Liu and Shih, 1957; Tabata and Tamanuki, 1940
Hymenoptera: Tetrastichidae				
Geniocerus xanthopus (Ratzeburg)	Larval parasitoid	Yes		Kolomiec, 1962
Hymenoptera: Trichogrammatidae				
Trichogramma dendrolimi Matsumura	Egg parasitoid	Yes	Yes	Kasparyan, 1965; Kolomiec, 1962; Yao et al., 2005; Yue et al., 1996
Trichogramma evanescens Westwood	Egg parasitoid	Yes		Liu and Shih, 1957
Trichogramma semblidis (Aurivillius)	Egg parasitoid	Yes		Kolomiec, 1962
Trichogramma sp.	Egg parasitoid	Yes		Kolomiec, 1962
Trichogramma dendrolimi Matsumura	Egg parasitoid	Yes	Yes	Matsumura, 1926b; Tabata and Tamanuki, 1940
Hymenoptera: Vespidae				
Polystes galicus L.	Larval predator	Yes		Kolomiec, 1962
Polystes chinensis Fabricius	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Vespa rufa sibirica Andre	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
Vespa japonica Sause	Larval predator	Yes	Yes	Matsumura, 1926a, 1926b
SPIDERS and MITES				
Acarina: Trombiidae				
Trombidium sp.	Predator	Yes		Kolomiec, 1962
Araneae: Araneidae				
Araneus marmoreus Clerck	Predator	Yes		Yue et al., 1996
Araneus ventricosus L.	Predator	Yes		Yue et al., 1996
Xysticus ephippiatus Simon	Predator	Yes		Yue et al., 1996
VIRUSES				

Table F-2 Reported biological control agents of *Dendrolimus sibiricus* Tschetverikov, the Siberian silk moth (SSM) and *D. superans* (Butler), the Sakhalin silk moth (SaSM)

Organism group Species	Host stage affected	*D.sibiricus*	*D.superans*	References
Dendrolimus sibiricus Cytoplasmic Polihydrosis Virus (DsCPV)	Larva	Yes		Yue et al., 1996
Dendrolimus sibiricus Nuclear Polihydrosis Virus (DsNPV)	Larva	Yes		Yue et al., 1996
BIRDS and OTHER VERTEBRATES				
Parus major artatus (Great tit bird)	Predator	Yes		Yue et al., 1996
Coloeus monedula L. (Jackdaws birds)	Pupal predators	Yes		Boldaruev, 1959
Cuculus canorus canorus (Cuckoo bird)	Predator	Yes		Yue et al., 1996
Eutamias sibiricus (Siberian Chipmunk)	Predator	Yes		Liu and Shih, 1957

Table F-3 Reported biological control agents of *Dendrolimus punctatus* (Walker), the Masson pine caterpillar (MPC).

Organism group Species	Host stage affected	References
BACTERIA		
Bacillus thuringiensis	Larva	Ying, 1986b
Bacillus thuringiensis subsp. dendrolimus	Larva	Li et al., 1984
FUNGI: ASCOMYCOTA		
Beauveria bassiana (Balsamo-Crivelli)	Larva	Hsiao, 1981; Jiang, 2000
Isaria farinosa (Holmskjold)	Larva	Ying, 1986b
Metarhizium anisopliae (Metschnikoff)	Larva	Jiang, 2000
INSECTS Order: Family		
Diptera: Tachinidae		
Blepharipa zebina Walker	Larval/Pupal parasitoid	Bassus, 1974; CABI, 2011b
Carcelia matsukarehae Shima	Larval parasitoid	Wang and Liu, 1993
Exorista xanthaspis (Wiedemann)	Larval/Pupal parasitoid	Xia and Zhou, 1992
Hymenoptera: Chalcididae		
Brachymeria donganensis Liao & Chen	Larval/Pupal parasitoid	

Table F-3 Reported biological control agents of *Dendrolimus punctatus* (Walker), the Masson pine caterpillar (MPC).

Organism group Species	Host stage affected	References
Brachymeria euploeae Westwood	Larval parasitoid	Chu, 1933
Brachymeria lasus Walker	Pupal parasitoid	Wang and Liu, 1993
Eurytoma sp.	Pupal parasitoid	Wang and Liu, 1993
Hymenoptera: Eupelmidae		
Anastatus gastropachae Ashmead	Egg Parasitoid	Xia and Zhou, 1992
Mesocomys albitarsis (Ashmead)	Egg parasitoid	Chu, 1937
Hymenoptera: Formicidae		
Camponotus japonicus Mayr	Larval/Pupal predator	Wang et al., 1991
Formica japonica Motschoulsky	Larval predator	CABI, 2011b
Polyrhachis dives Smith	Larval predator	Hsiao, 1981
Hymenoptera: Ichneumonidae		
Casinaria nigripes (Gravenhorst)	Pupal parasitoid	Qian, 1987
Pimpla disparis Viereck	Pupal parasitoid	Wang and Liu, 1993
Theronia zebra (Vollenhoven)	Larval parasitoid	Wang and Liu, 1993
Xanthopimpla japonica Kreiger	Pupal parasitoid	Chu, 1937
Xanthopimpla pedator Fabricius	Pupal parasitoid	Wang and Liu, 1993
Hymenoptera: Scelionidae		
Telenomus dendrolimi (Matsumura)	Egg parasitoid	Chu, 1937; Xu et al., 2006
Telenomus theophilae (Wu & Chen)	Egg parasitoid	Wei et al., 2005
Hymenoptera: Trichogrammatidae		
Trichogramma chilonis Ishii (attacks eggs)	Egg parasitoid	
Trichogramma dendrolimi Matsumura	Egg parasitoid	Peng et al., 1998; Shen et al., 1992; Sun et al., 1990
Trichogramma evanescens Westwood	Egg parasitoid	Chu, 1937
MICROSPORIDIA		
Nosema bombycis Naegeli.	Larval/Pupal parasite	Lu et al., 1986
VIRUSES		

Table F-3 Reported biological control agents of *Dendrolimus punctatus* (Walker), the Masson pine caterpillar (MPC).

Organism group Species	Host stage affected	References
cytoplasmic polyhedrosis virus	Larva	Hsiao, 1981; Ying, 1986b
BIRDS and other VERTE-BRATES		
Parus major	Larval predator	Wang and Liao, 1990
Parus monticolus yunnanensis	Larval predator	Wang and Liao, 1990
Passer rutilans	Larval predator	Wang and Liao, 1990