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Global review of forest pests and diseases

Cover photographs:
Left: Pine moth (*Dendrolimus spectabilis*) caterpillar feeding on *Pinus densiflora*, Democratic People's Republic of Korea (G. Allard)
Centre: Dothistroma needle blight (*Mycosphaerella pini*) on *Pinus contorta*, United States (Bugwood.org/USDA Forest Service Archive/2251050)
Right: Damage by the introduced beaver *Castor canadensis* to *Nothofagus pumilio*, Tierra del Fuego, Chile (G. Allard)

Global review of forest pests and diseases

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A thematic study prepared in the framework of the Global Forest Resources Assessment 2005

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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[1] Pests profiled in Part II are noted by an asterisk (*) when mentioned throughout the text.

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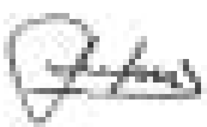
Foreword

Insect pests, diseases and other biotic agents have considerable impacts on forests and the forest sector. They can adversely affect tree growth and the yield of wood and non-wood products. Damage caused by forest pests can significantly reduce wildlife habitat thereby reducing local biodiversity and species richness. They can alter natural forest landscapes by decimating one or more tree species as has been observed in eastern American forests as a result of chestnut blight and throughout the Northern Hemisphere because of Dutch elm disease. Some pests have necessitated changes in management regimes often forcing forest managers to switch to alternative tree species in plantations; for example, the failed attempts in many parts of the world to establish mahogany plantations because of the presence of mahogany shoot borers (*Hypsipyla* spp.). Pathogens may also limit the sites on which species can be grown successfully outside their natural range as has been experienced with red band needle blight (*Mycosphaerella pini*) and western gall rust (*Endocronartium harknessii*) infecting *Pinus radiata.*

While abundant literature is produced on forest pests and diseases, a comprehensive consideration of the issues at regional and global levels has been lacking. The first major global meeting on forest insect pests and diseases was held in Oxford, UK in 1964: the FAO and International Union of Forest Research Organizations (IUFRO) Symposium on Internationally Dangerous Forest Diseases and Insects. A second meeting held in New Delhi, India in 1975 continued the process of cooperation. Since the reports of these meetings, little information has been available at the global level that is not pest specific.

Understanding the state of global forest health requires international cooperation and the gathering and dissemination of accurate and timely information. As part of the Global Forest Resources Assessment 2005 (FRA 2005), countries reported on area affected by insect pests, diseases and other disturbances. This information was supplemented by a thematic study reviewing forest pests in 25 countries. Part I of this publication summarizes the results of these data by region. Part II presents profiles of some globally important forest pest species and Part III discusses select forest trees species and their associated pests. The information provided in this publication will assist forest health specialists, forest managers and policy-makers worldwide to make informed decisions.

During the preparation of this document continuous updates were necessary due to the discovery of previously unrecorded pest problems in new locations, countries and regions. The report is not comprehensive as new information is continually becoming available.



J.A. Prado
Director, Forest Management Division
FAO Forestry Department

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Acronyms

ACIAR	Australian Centre for International Agricultural Research
AFWC	African Forestry and Wildlife Commission
APFC	Asia-Pacific Forestry Commission
APFISN	Asia-Pacific Forest Invasive Species Network
APPPC	Asia and Pacific Plant Protection Commission
CA	Comunidad Andina
CBD	Convention on Biological Diversity
CIBC	Commonwealth Institute of Biological Control
CIE	Commonwealth Institute of Entomology
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLRV	Cherry leaf roll nepovirus
COSAVE	Comité de Sanidad Vegetal del Cono Sur
CPPC	Caribbean Plant Protection Commission
EPPO	European and Mediterranean Plant Protection Organization
EU	European Union
FISNA	Forest Invasive Species Network for Africa
FRA	Global Forest Resources Assessment
FSC	Forest Stewardship Council
GISP	Global Invasive Species Programme
IAPSC	Inter-African Phytosanitary Council
ICP Forests	International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
ICPM	Interim Commission on Phytosanitary Measures
IFQRG	International Forestry Quarantine Research Group
IOBC	International Organization for Biological Control of Noxious Animals and Plants
IPM	Integrated pest management
IPPC	International Plant Protection Convention
ISPMs	International Standards for Phytosanitary Measures
ISSG	Invasive Species Specialist Group
IUCN	International Union for the Conservation of Nature
IUFRO	International Union of Forest Research Organizations
LACFC	Latin American and Caribbean Forestry Commission
LRTAP	Convention on Long Range Transboundary Air Pollution
MCPFE	Ministerial Conference for the Protection of Forests in Europe
NAFC	North American Forest Commission
NAPPO	North American Plant Protection Organization
NEFC	Near East Forestry Commission
NENFHIS	Near East Network on Forest Health and Invasive Species
NEPPO	Near East Plant Protection Organization
NPPO	National Plant Protection Organization
NPV	Nuclear polyhedrosis virus
OIRSA	Organismo Internacional Regional de Sanidad Agropecuaria
RPPO	Regional Plant Protection Organization
SLU	Swedish University of Agricultural Sciences
UNECE	United Nations Economic Commission for Europe
WMO	World Meteorological Organization

Introduction

Forests are complex ecosystems that provide a variety of valuable products, such as timber, fuelwood, fibre and non-wood forest products, and contribute to the livelihoods of rural communities. They also provide vital ecosystem services, such as combating desertification, protecting watersheds, maintaining biodiversity, and enhancing carbon sequestration, and play an important role in preserving social and cultural values. It is critically important to protect these valuable resources from disturbances such as fire, pollution, invasive species, insects and diseases.

While they are integral components of forest ecosystems, insects and diseases have considerable influence on the health of forests, trees outside forests and other wooded lands. They can adversely effect tree growth, vigour and survival, the yield and quality of wood and non-wood products, wildlife habitat, recreation, aesthetics and cultural values. Forest insect pests and diseases may also result in the limitation of plantation programmes, the abandonment of a given tree species and the necessity to clearcut large areas dominated by infested trees.

Forests need to be managed so that the risks and impacts of unwanted disturbances are minimized. Measures to protect forests from insect pests and diseases are an integral part of sustainable forest management. The importance of considering the impacts of insect pests and diseases on forests and the forest sector has been recognized for some time. Effective pest management requires reliable information – information on the pests themselves, their biology, ecology, and distribution, their impacts on forest ecosystems and possible methods of control. While much qualitative information on insect pests and diseases exists at local, national and even regional scales, little comprehensive, quantitative information is available at the global level. Typically more information is available on pests of trees in industrialized rather than non-industrialized countries and also for pests of trees grown in commercially valuable planted forests (which include plantation forests and planted semi-natural forests) compared to pests in naturally regenerated forests. Virtually nothing is known of the pests associated with those trees harvested from naturally regenerated forests, at least in the tropics.

FAO ACTIVITIES IN FOREST HEALTH

FAO is the only international organization working on forest health and protection at the global scale. Activities in the FAO forest protection and health programme aim to assist, advise and support countries to protect the health and vitality of forests, forest ecosystems and trees outside forests, with special reference to insects, diseases and other harmful biotic and abiotic agents. FAO provides advice on preventive measures, pest management and recommended actions to minimize risks of transboundary transfer. It also offers assistance to countries not only in response to pest outbreaks and emergencies but also in establishing long-term prevention and forest protection strategies. FAO also hosts the Secretariat of the International Plant Protection Convention (IPPC) (Box 1).

COLLECTING GLOBAL FOREST HEALTH INFORMATION

FAO gathers information to obtain an ever more complete picture of global forest health. The following activities are some examples that have helped contribute to closing the information gap regarding forest health.

With the cooperation of experts from member countries, FAO compiled data for a global information system on the impact of insect pests and disease outbreaks on forests (www.fao.org/forestry/25350). The pilot system was designed to document, BOX 1

The International Plant Protection Convention

The International Plant Protection Convention (IPPC) is an international treaty to secure action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control. The IPPC is governed by the Commission on Phytosanitary Measures (CPM) which adopts International Standards for Phytosanitary Measures (ISPMs). These standards are developed and approved through an international consultative process, and are recognized under the WTO Agreement on the Application of Sanitary and Phytosanitary Measures.

ISPMs have direct relevance to the forest sector including guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms (ISPM No. 3), pest risk analysis (ISPM Nos. 2, 11, 21), pest eradication programmes (ISPM No. 9), pest status and reporting (ISPM Nos. 8, 17), and regulating wood packaging materials in international trade (ISPM No. 15). In addition, the International Forestry Quarantine Research Group (IFQRG) acts as an advisory body to the IPPC and addresses critical forestry quarantine issues through discussion and collaborative research.

Regional Plant Protection Organizations (RPPOs) are intergovernmental organizations that assist in the coordination of National Plant Protection Organizations (NPPO), gather and disseminate information and assist in developing international standards.

The RPPOs include:

- Asia and Pacific Plant Protection Commission (APPPC) (formerly the Plant Protection Commission for Southeast Asia and the Pacific Region) created in 1956;
- European and Mediterranean Plant Protection Organization (EPPO), 1951;
- Inter-African Phytosanitary Council (IAPSC), 1954;
- Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA), 1953;
- Caribbean Plant Protection Commission (CPPC), 1967;
- Comunidad Andina (CA), 1969;
- North American Plant Protection Organization (NAPPO), 1976;
- Comite de Sanidad Vegetal del Cono Sur (COSAVE), 1980;
- Pacific Plant Protection Organization (PPPO), 1994.

A tenth RPPO, the Near East Plant Protection Organization (NEPPO), has been agreed upon and ratified by eight countries in the region. However, two more ratifications are required for it to enter into force.

analyse and make current information about forest health available at the country level in order to increase awareness of the severe problems related to insect pests and diseases worldwide and to provide up to date information for policy and forest management planning. A database on the incidence and extent of insect pests and diseases affecting forests over time was created and subsequently tested and a critical economic review of its contents was then carried out. To date, qualitative information on forest health issues has been collected for 64 countries, mostly developing countries and countries in transition. The information was gathered through different sources including FAO field project reports, country reports and a test questionnaire sent out to selected technical experts.

To attempt to quantify the impacts of the many factors that affect the health and vitality of a forest, the Global Forest Resources Assessment 2005 (FRA 2005) asked countries to report on the area of forest adversely affected by disturbances, including forest fires, insects, diseases and other disturbances such as weather-related damage (FAO, 2006). Most countries, however, were not able to provide reliable quantitative information because they do not systematically monitor these variables for many

TABLE 1
Countries included in the forest pest overviews

Region	Countries
Africa	Ghana, Kenya, Malawi, Mauritius, Morocco, South Africa, Sudan
Asia and the Pacific	China, India, Indonesia, Mongolia, Thailand
Europe	Moldova, Romania, Russian Federation
Latin America and the Caribbean	Argentina, Belize, Brazil, Chile, Colombia, Honduras, Mexico[a], Uruguay
Near East	Cyprus, Kyrgyzstan

[a] For the purposes of this study, Mexico has been included in Latin America and the Caribbean

reasons. As a result, FAO has been investigating ways to adapt the forest health and vitality reporting tables for the 2010 assessment in order to improve the quality of data reported and encourage monitoring of forest health.

A review of forest pests in both naturally regenerated forests and planted forests was carried out from 2005 to 2008 in 25 countries, including a number of major forest countries (Brazil, China, Indonesia), in Africa, Asia and the Pacific, Europe, Latin America and the Caribbean and the Near East (Table 1). Information was collated from many sources including expert contacts in the countries, the Internet and literature searches; where possible all data have been evaluated in country. Specifically, information was gathered on insect pests, diseases and other pests (nematodes, mites, parasitic plants and mammals) impacting naturally regenerated and planted forests. A section was also devoted to national capacities for forest health protection and included information on government and private landowner activities as well as monitoring and detection, data management and pest management activities. This activity is a continuous process and FAO will continue to review forest pests in other countries.

ABOUT THIS BOOK

Part I analyses the information gathered in the country reports to help identify the key issues in each region regarding forest health and protection and help further discussions on regional forest pests and capacities for pest management. Quantitative forest health information gathered through FRA 2005 is also presented where available. Further information from the region that was not highlighted in the country papers is discussed to present a more inclusive picture of forest health in each region. A section on North America (Canada and the United States of America) is also included. Part I concludes with a global analysis of this information.

Part II provides detailed profiles of some globally important transboundary forest pest species. These profiles are also available online at www.fao.org/forestry/pests, where additional pests will be included over time.

Part III presents profiles of the pests associated with some select forest tree species. This section was prepared by M.J.W. Cock, with assistance from J. Knight, in 2002. The information was extracted and adapted from the CABI Forestry Compendium (www.cabi.org/compendia/fc) to illustrate the diversity of pest and disease problems in important forest trees. The species were chosen to represent important forest tree genera. For any given genus, only one or two representative species are discussed, although main genera such as *Pinus* and *Eucalyptus* obviously have dozens of important species.

Annexes provide the raw data collected from the countries, by region, and a table of the species mentioned in the publication.

Throughout this book, an asterisk (*) indicates species that are profiled in Part II.

PART I

Regional and global analysis

Africa

The total number of pest species reported from the seven countries in the region was 99 (Figure 1; Table 2). Insect pests were the most frequently reported pest type, followed by pathogens. Only one mammalian pest was reported, the indigenous Barbary macaque (*Macaca sylvana*) from Morocco.

Almost 60 percent of the pests reported were indigenous, while the rest were introduced. The majority were reported exclusively in planted forests, about 30 percent in naturally regenerated forests and 11 percent in both types of forest. Malawi was the only country that reported more pests in naturally regenerated forests.

Broadleaf tree species were the most commonly reported host type. Twenty-eight percent of the pests were recorded on conifers while 8 percent of pests were reported as infesting both broadleaves and conifers. Pests recorded in Kenya were evenly split between broadleaf and conifer trees, while Morocco reported conifers as the most common host. On the African continent, conifers are mainly found in North Africa and in planted forests in eastern and southern Africa.

Lepidopteran (butterflies and moths) and coleopteran (beetles and weevils) species were the most common insect pests recorded in almost all countries (Figure 2), although Kenya reported more Hemiptera (true bugs, aphids and hoppers), and Malawi reported more Isoptera (termites) species. The most common pathogens reported from Africa were species from the phylum Ascomycota.

Countries profiled in the region

FIGURE 1
Number of forest pest species reported, Africa

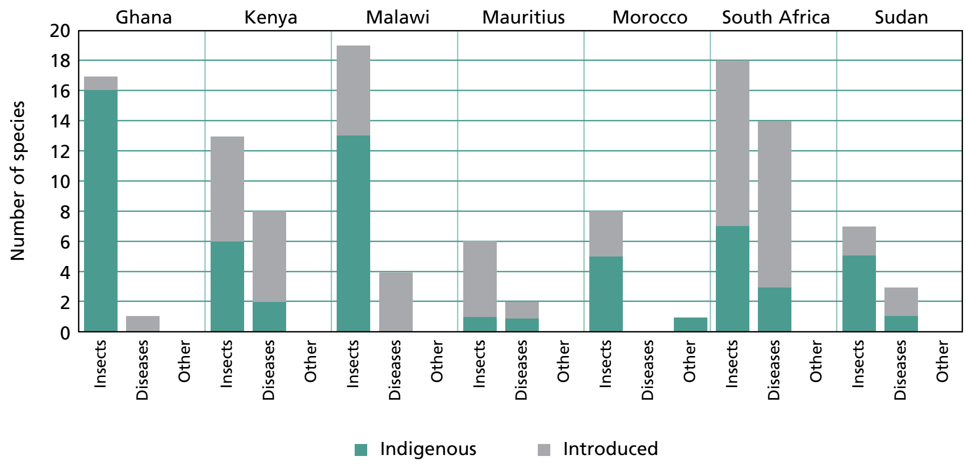
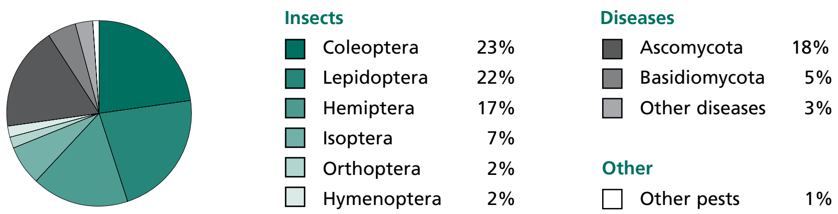


FIGURE 2
Most prevalent pests, Africa



SPECIES FOUND IN MORE THAN ONE COUNTRY

A number of forest pests were reported from more than one country in the region (Table 3). All transboundary species reported from Africa are introduced species from other continents.

Nine insect pest species, out of a total of 72, were recorded from more than one country in the region. All of these insect pests were recorded in planted forests. Three species (*Cinara cupressivora**, *Eulachnus rileyi* and *Pineus pini*) were recorded on conifers and the remaining six were recorded on broadleaf trees.

The longicorn borers *Phoracantha recurva** and *P. semipunctata** and the leaf-feeding curculionid *Gonipterus scutellatus** are significant pests of eucalypts. *Heteropsylla cubana** is a pest of the fast-growing Central American tree, *Leucaena leucocephala*, which has been widely planted in the tropics since the 1970s for agroforestry, wood production and fodder. The shoot borer, *Hypsipyla robusta**, is a major pest of several high quality timber species including African mahogany (*Khaya* spp.), mahogany (*Swietenia macrophylla, S. mahagoni*), and teak (*Tectona* spp.). The blue gum chalcid, *Leptocybe invasa**, is a relatively new threat to planted eucalypt forests in Africa, reported first from Kenya in 2002 and from South Africa in July 2007. This pest is also known to occur in Morocco although the date of introduction is unknown.

Three introduced pathogens were recorded from more than one country. *Armillaria mellea** was recorded in both naturally regenerated and planted forests, while *Mycosphaerella pini** and *Sphaeropsis sapinea* were reported exclusively in planted forests. All three were recorded on conifers, although *A. mellea* was also noted to be a pest of broadleaf trees.

TABLE 2
Summary of the data on forest pest species reported, Africa

Pest type	Number of pest species						
	Total	In naturally generated forests	In planted forests	In both types of forest	On broadleaf	On conifer	On both host types
Indigenous species							
Insects	53	26	25	2	39	12	2
Diseases	6	1	1	4	3	1	2
Other	1	0	0	1	0	1	0
Introduced species							
Insects	19	0	19	0	10	9	0
Diseases	20	2	14	4	11	5	4
Other	0	0	0	0	0	0	0
Total	**99**	**29**	**59**	**11**	**63**	**28**	**8**

TABLE 3
Forest pest species found in more than one country, Africa

Pest species	Order/phylum: family	Countries of occurrence	Indigenous/ introduced	Type of forest	Host type
Insects					
*Cinara cupressivora**	Hemiptera: Aphididae	Kenya, Malawi, Mauritius	Introduced	Planted	Conifer
Eulachnus rileyi	Hemiptera: Aphididae	Kenya, Malawi	Introduced	Naturally regenerated, planted	Conifer
*Gonipterus scutellatus**	Coleoptera: Curculionidae	Kenya, Mauritius, South Africa	Introduced	Planted	Broadleaf
*Heteropsylla cubana**	Hemiptera: Psyllidae	Kenya, Malawi, Mauritius, Sudan	Introduced	Planted	Broadleaf
*Hypsipyla robusta**	Lepidoptera: Pyralidae	Ghana, Mauritius	Introduced	Planted	Broadleaf
*Leptocybe invasa**	Hymenoptera: Eulophidae	Kenya, Morocco, South Africa	Introduced	Planted	Broadleaf
*Phoracantha recurva**	Coleoptera: Cerambycidae	Malawi, Morocco, South Africa	Introduced	Planted	Broadleaf
*Phoracantha semipunctata**	Coleoptera: Cerambycidae	Malawi, Morocco, South Africa	Introduced	Planted	Broadleaf
Pineus pini	Hemiptera: Adelgidae	Kenya, Malawi, South Africa	Introduced	Planted	Conifer
Diseases					
*Armillaria mellea**	Basidiomycota: Marasmiaceae	Kenya, Malawi, Sudan	Introduced	Naturally regenerated, planted	Broadleaf, conifer
*Mycosphaerella pini**	Ascomycota: Mycosphaerellaceae	Kenya, South Africa	Introduced	Planted	Conifer
Sphaeropsis sapinea	Ascomycota: Incertae sedis	Kenya, South Africa	Introduced	Planted	Conifer

CAPACITY FOR FOREST HEALTH PROTECTION

Monitoring and detection

Most countries do not carry out routine monitoring and detection. Such activities are often informal in nature involving observations made by foresters and forest workers while carrying out other activities in the field. In some countries, monitoring activities have been carried out for specific pests, such as aerial surveys to detect damage by *Cinara cupressivora** in Kenya and the mapping of winter nests and placement of pheromone traps to detect *Thaumetopoea pityocampa** in Morocco. In South Africa, disease development in planted forests is regularly monitored. A major impediment to effective monitoring and detection activities is the lack of highly trained and skilled people capable of identifying insects and diseases as causal agents of damage to forests. This is compounded by a lack of infrastructure and transport.

Data management

Of the little information available on forest health in the African countries, most is qualitative in nature; very little quantitative data exist for most countries. Some data are available for specific pests, such as *Cinara cupressivora** in Kenya, Malawi and Mauritius and the tree locust (*Anacridum melanorhodon*) in the Sudan. Impediments to forest health data management include lack of trained personnel, inadequate data storage facilities and low capacity for analysing large quantities of data. Considerable data are stored as hard copy, whereas to be of value for predictive forecasting they need to be transferred to electronic databases.

As part of the Global Forest Resources Assessment (FRA) 2005, FAO asked countries to report on the impact of insect pests and diseases on their forests for two reporting periods: 1990 (average from 1988 to 1992); and 2000 (1998 to 2002). Most countries did not provide any solid, quantitative information through the country correspondent and only two provided data on the area of forests impacted. Morocco reported that over 16 000 ha (1990) and 37 000 ha (2000) of forest were damaged by insect pests while other disturbances damaged a further 2 500 ha (2000). South Africa reported that 2 250 ha (1990) and 919 ha (2000) of planted forests were damaged by weather, diseases, insects, animals and rodents.

Pest management

Some pest management activities, such as physical removal of infested trees, the application of chemical and biological pesticides, classical biological control, and the planting of pest tolerant tree species, have been carried out to varying degrees in each country. Most activities are target specific and include classical biological control programmes, e.g. for management of *Cinara cronartii* in South Africa and *Heteropsylla cubana** in Kenya and Mauritius, and *Cinara cupressivora** in Kenya, Malawi and Mauritius. Aerial application of chemical and biopesticides has been carried out in Morocco for management of *Thaumetopoea pityocampa**. Most countries lack comprehensive forest pest management plans or preventative measures.

Ownership

In most of the countries, the majority of the forests are in the public domain. In privately owned and managed forests, pest management activities are often carried out in collaboration with national agencies and departments.

ADDITIONAL INFORMATION

In general, there is a broad trend in the region towards recognizing environmental and biodiversity concerns including forest health and protection. However, information on forest health is scarce and, as part of FRA 2005, only five countries from the entire continent reported quantitative data pertaining to insect pests and diseases. This is insufficient for trend analysis.

African forests are subject to the impact of a number of indigenous mammalian pests such as baboons (*Papio* spp.) and the African elephant (*Loxodonta africana*). Baboons can cause considerable damage to pine plantations in southern Africa, particularly in Malawi, Zambia and Zimbabwe, where they strip bark, which results in tree death. They may also attack *Eucalyptus*, *Acacia* and *Cupressus* plantations. In East Africa the elephant may cause death of young trees by rubbing against saplings and by pulling branches during feeding.

The African continent faces severe challenges from invasive forest species. An example is the blue gum chalcid, *Leptocybe invasa**, which damages young eucalypt trees and seedlings. A recent introduction into Kenya, Morocco and South Africa, it is also found in the forests of Algeria, Uganda and the United Republic of Tanzania. This pest has also been reported in Asia and the Pacific, Europe and the Near East. Other pests introduced into the continent in the last five years include: *Cinara pinivora** in Malawi, *Coniothyrium zuluense* in Ethiopia, *Thaumastocoris peregrinus* and *Coryphodema tristis* in South Africa and *Gonometa podocarpi* in the United Republic of Tanzania. All of these pose threats to bordering countries.

Conifer aphids have been a major problem in the region for several decades particularly in countries where planted conifer forests are common. While Kenya, Malawi and Mauritius reported the cypress aphid, *Cinara cupressivora**, as a pest of cypress and cedar trees, it is also known to be or has been a major problem in other African countries including Burundi, the Democratic Republic of the Congo, Ethiopia, Rwanda, South Africa, Uganda, the United Republic of Tanzania, Zambia and Zimbabwe (Ciesla, 1991; Ciesla, 2003a). Kenya and Malawi also reported the pine needle aphid, *Eulachnus rileyi*, which has become a major pest of planted pines throughout eastern and southern Africa since its initial introduction into the region (South Africa, Zambia, Zimbabwe) in the late 1970s (Murphy, Abraham and Cross, 1991). The pine woolly aphid, *Pineus pini* has attained pest status worldwide. While it has been reported from Kenya, Malawi and South Africa, information on this pest's occurrence in other African countries is lacking, with the exception of the United Republic of Tanzania.

The European woodwasp, *Sirex noctilio**, now established in South Africa, is a significant pest of conifer forests in many other countries outside Africa as well, causing considerable damage and cost to local economies. Efforts are being made to address the severe threat of this pest to the African continent, including a meeting in 2007, hosted by South Africa, to review current knowledge and increase the understanding of *Sirex noctilio* and its worldwide threat to forestry (www.fabinet.up.ac.za/sirex/index).

The leucaena psyllid, *Heteropsylla cubana**, noted as a significant pest of *Leucaena leucocephala* in Kenya, Malawi, Mauritius and the Sudan, is also a well-known pest in leucaena growing areas in Burundi, Ethiopia, Mozambique, Réunion, the United Republic of Tanzania, Uganda and Zambia (FAO, 2001; Nair, 2001).

Native to Australia, *Phoracantha recurva** is a pest of planted forests in Malawi, Morocco, and South Africa and is also known to occur in Tunisia and Zambia as well as in other regions.

Apate spp., indigenous small borer beetles, have been reported as pests of broadleaf planted forests in Kenya (*A. indistincta* and *A. monachus*) and Ghana (*A. terebrans*).

Fungal *Armillaria* spp., which cause Armillaria root disease, are found throughout the temperate and tropical regions of the world. *Armillaria mellea** has been reported from Kenya, Malawi and the Sudan. *A. fuscipes* has been identified as the main cause of Armillaria root disease in South Africa. *A. heimii* is recorded in Kenya. Unidentified *Armillaria* species were reported in Mauritius. *Sphaeropsis sapinea*, reported from Kenya and South Africa, is also a cosmopolitan fungus; it causes shoot blight and canker disease on conifer trees throughout the world. Specific information on the occurrence of these pathogens in other African countries is lacking.

The red band needle blight, *Mycosphaerella pini**, reported from Kenya and South Africa, is also known as a pest in Malawi, the United Republic of Tanzania, Uganda, Zambia and Zimbabwe (EPPO/CABI, 1997). This fungal disease, previously referred to as Dothistroma blight, has contributed to the decline of *Pinus radiata* plantations in Kenya.

*Botryosphaeria dothidea**, *B. eucalypticola* and *B. eucalyptorum* are pests in South African broadleaf planted forests. Kenya and Malawi both reported unidentified *Botryosphaeria* sp. in broadleaf planted forests and broadleaf and conifer naturally regenerated forests.

Dieback and declines of uncertain cause affect junipers and cedars in several countries in the region. Some species affected include *Cedrus atlantica* in Algeria and Morocco, representing the world's genetic base for Atlantic cedars; *Juniperus phoenicea* in the Libyan Arab Jamahiriya; and *Juniperus procera* in Kenya.

REGIONAL PEST MANAGEMENT EFFORTS

The Forest Invasive Species Network for Africa (FISNA), created by a group of African scientists with the support of the FAO and the United States Forest Service, coordinates the collation and dissemination of information relating to forest invasive species in sub-Saharan Africa. The network raises regional awareness on forest invasive species; encourages the publication and sharing of research results, management and monitoring strategies; and acts as a link between and among experts, institutions, networks and other stakeholders concerned with forest invasive species in the region. Up-to-date information on new invasions is disseminated through a Web site (www.fao.org/forestry/26951).

Plant protection and phytosanitary issues are addressed by the Inter-African Phytosanitary Council (IAPSC) which is a Regional Plant Protection Organization (RPPO) of the International Plant Protection Convention (IPPC).

Asia and the Pacific

The total number of forest pest species reported from the five countries in the region was 138 (Figure 3). Insect pests were the most frequently reported pest type (Table 4). Other pests included the pine wood nematode (*Bursaphelenchus xylophilus**) and the mouse (*Apodemus* spp.) from China. Almost 90 percent of the pest species reported are indigenous.

Considerably more pests (77 percent) were reported in planted forests in all countries with the exception of Mongolia, where forest pests were reported equally in naturally regenerated and planted forests. The world's highest plantation rates are found in Asia, particularly China, which is one of the top ten countries for productive forest plantations (FAO, 2006b).

Countries profiled in the region

Seventy-eight percent of forest pests were recorded on broadleaf trees, 15 percent on conifers and the remaining 7 percent were recorded on both host tree types. Mongolia was the only country to report more pests on conifer trees, which is consistent with the large area of coniferous forests in the country, particularly in northern areas.

The top two insect pest orders reported in the region were Coleoptera and Lepidoptera (Figure 4). Ascomycota species were the most commonly reported pathogens.

Although this study is primarily concerned with forest pests, the coconut leaf beetle, *Brontispa longissima*, is also included because of its high economic importance to coconuts and ornamental palms in more than one country in the region.

FIGURE 3
Number of forest pest species reported, Asia and the Pacific

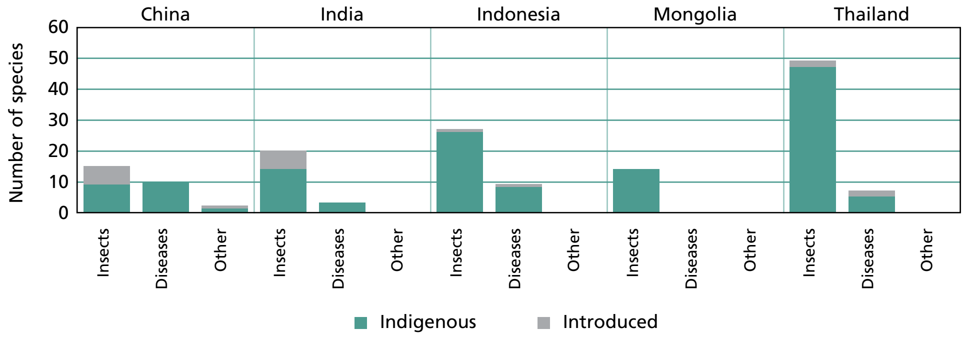


FIGURE 4
Most prevalent species, Asia and the Pacific

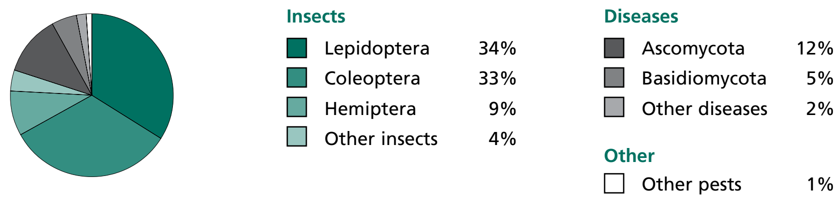


TABLE 4
Summary of the data on forest pest species, Asia and the Pacific

Pest type	Number of pest species						
	Total	In naturally regenerated forests	In planted forests	In both types of forest	On broadleaf	On conifer	On both host types
Indigenous species							
Insects	99	12	68	19	77	15	7
Diseases	24	0	24	0	23	0	1
Other	1	0	1	0	0	0	1
Introduced species							
Insects	11	1	10	0	6	5	0
Diseases	3	0	3	0	3	0	0
Other	1	0	0	1	0	1	0
Total[a]	**138**	**13**	**105**	**20**	**108**	**21**	**9**

[a] *Note*: *Brontispa longissima* is indigenous to Indonesia but has been introduced in Thailand and China; it is counted in both rows (indigenous and introduced) but is not counted twice in the totals.

SPECIES FOUND IN MORE THAN ONE COUNTRY

A number of species were noted to be pests in two or more countries in the region (Table 5). All but one, *Heteropsylla cubana**, are indigenous.

Six of these were recorded in planted forests and seven in both types of forest. Nine species were pests of broadleaf trees, two of conifers and two of both host tree types. Of the 13 species, 12 were insect pests, more than half of which were lepidopteran species.

The Siberian caterpillar, *Dendrolimus sibiricus**, has caused considerable damage to the naturally regenerated forests of China and Mongolia and also to planted forests in Mongolia, especially those planted with *Larix sibirica*.

The Asian gypsy moth, *Lymantria dispar**, was reported on both broadleaf and conifer trees in naturally regenerated forests in China and Mongolia; Mongolia also reported the pest in planted forests of both host types. This pest is a destructive defoliator of many broadleaf and conifer trees, including *Betula*, *Larix*, *Populus*, *Pinus*, *Quercus*, *Salix*, and *Ulmus* species, and is of quarantine concern in many regions of the world.

TABLE 5
Species found in more than one country, Asia and the Pacific

Pest species	Order/phylum: family	Countries of occurrence	Type of forest	Host type
Insects				
Brontispa longissima	Coleoptera: Chrysomelidae	China, Indonesia, Thailand	Planted	Coconut palm
Calopepla leayana	Coleoptera: Chrysomelidae	India, Thailand	Planted	Broadleaf
Coptotermes curvignathus	Isoptera: Rhinotermitidae	Indonesia, Thailand	Planted	Broadleaf, conifer
*Dendrolimus sibiricus**	Lepidoptera: Lasiocampidae	China, Mongolia	Naturally regenerated, planted	Conifer
Eutectona machaeralis	Lepidoptera: Pyralidae	India, Thailand	Naturally regenerated, planted	Broadleaf
*Heteropsylla cubana**	Hemiptera: Psyllidae	India, Indonesia, Thailand	Planted	Broadleaf
Hyblaea puera	Lepidoptera: Hyblaeidae	India, Indonesia, Thailand	Naturally regenerated, planted	Broadleaf
*Hypsipyla robusta**	Lepidoptera: Pyralidae	India, Indonesia, Thailand	Planted	Broadleaf
*Ips sexdentatus**	Coleoptera: Scolytidae	Mongolia, Thailand	Naturally regenerated, planted	Conifer
*Lymantria dispar** (Asian strain)	Lepidoptera: Lymantriidae	China, Mongolia	Naturally regenerated, planted	Broadleaf, conifer
Xyleutes ceramica	Lepidoptera: Cossidae	Indonesia, Thailand	Naturally regenerated, planted	Broadleaf
Zeuzera coffeae	Lepidoptera: Cossidae	Indonesia, Thailand	Naturally regenerated, planted	Broadleaf
Diseases				
Agrobacterium tumefaciens	Rhizobiales: Rhizobiaceae	China, Indonesia	Planted	Broadleaf

Hyblaea puera, *Eutectona machaeralis* and *Xyleutes ceramica* are all major pests of teak in areas of Asia.

Zeuzera coffeae, reported from India and Thailand, typically attacks coffee plants but is also known to cause damage to a wide range of other hosts including *Chukrasia tabularis*, *Eucalyptus deglupta*, *Terminalia brassii*, and species of *Acalypha*, *Psidium*, *Crataegus*, *Citrus*, *Theobroma* and *Casuarina.*

The shoot borer, *Hypsipyla robusta**, is a significant pest of several species of high quality timber species in the region including *Cedrela toona*, *Chukrasia tabularis*, *Swietenia macrophylla*, *S. mahogani*, *Toona australis* and *T. ciliata* as well as species of *Cedrella* and *Tectona.*

Three beetle species were reported: *Brontispa longissima*, a major pest of coconut palms; *Calopepla leayana* a significant defoliator of gamhar, *Gmelina arborea*; and the six-spined engraver beetle, *Ips sexdentatus**, a major pest of many conifer species including *Picea*, *Pinus*, and *Larix*.

Coptotermes curvignathus is a subterranean termite that attacks a wide range of trees and is capable of killing healthy trees. In Southeast Asia, this species is a pest of many planted forest species including all species of conifers, rubber trees (*Hevea brasiliensis*), *Acacia mangium*, *Paraserianthes falcataria* and *Gmelina arborea*.

Recorded in three of the five countries, *Heteropsylla cubana** is a significant pest of *Leucaena leucocephala*, a fast-growing legume native to Mexico and Central America that has been widely planted throughout the region as a source of fuelwood and fodder and for use in agroforestry systems. Between 1985 and 1988, this insect spread rapidly across the Asia and the Pacific region (FAO, 2001).

Only one pathogen was noted to occur in more than one country, the bacterial disease, *Agrobacterium tumefaciens*, which causes significant damage to planted poplar forests in China and planted dipterocarps in Indonesia.

CAPACITY FOR FOREST HEALTH PROTECTION

Monitoring and detection

For the most part, monitoring and detection activities are not part of routine management practices, although some surveillance has been carried out to detect specific problem pests.

In China, a variety of methods are used, ranging from informal surveys to baited traps for specific pests such as the bark beetle, *Dendroctonus valens**. A risk rating system has also been developed for the detection of the pine caterpillar, *Dendrolimus punctatus*, in China.

In Mongolia, some pest surveys have been carried out by scientific institutes. Through an FAO emergency project to assist with outbreaks of the Siberian caterpillar, *Dendrolimus sibiricus**, surveys were carried out to determine the extent of the pest and the subsequent damage. In addition, pest management plans were developed which included monitoring and surveillance.

In both India and Indonesia it was noted that monitoring and detection activities are informal and limited, although a few special surveys have been conducted.

Data management

Most of the information available on forest pests and diseases is qualitative, although some information on the area affected by a few pest species was noted from China and India. No information was found on the capacity for data management in Mongolia and Thailand. A large number of qualitative reviews of pests and damage are available for Indonesia.

Four of the five countries provided data on the area affected by insects and/or diseases for FRA 2005. Two of these countries, China and Mongolia, provided data for both reporting periods, 1990 (average from 1988 to 1992) and 2000 (1998 to 2002). No information was reported from Thailand.

For the 2000 period, China reported that almost 6.2 million hectares of forest were damaged by insects, 883 000 ha by diseases and 820 000 ha by *Apodemus* spp. (mice). For the 1990 period, China reported that almost 7.9 million hectares were damaged by insects, 1.8 million hectares by diseases and 755 000 ha by mice. India reported 1 million hectares of damage due to insects and 8.4 million hectares damaged by diseases for the 2000 period. Mongolia reported that insects damaged 28 000 ha of forest in 1990 and almost 2.8 million hectares for the 2000 reporting period. Indonesia reported that 2 710 ha of forest were impacted by insects for the 1990 reporting period and that no disturbances by insects and diseases occurred during the 2000 period.

Pest management

A number of pest management activities, including use of chemical, biological and silvicultural methods, are carried out in the selected countries, primarily to target specific forest pests.

China has removed more than 200 million infested trees to control outbreaks of the Asian longhorned beetle, *Anoplophora glabripennis**, and has successfully used egg parasitoids and a fungus (*Beauvaria bassiana*) to control the pine caterpillar, *Dendrolimus punctatus*. Some tactics applied for controlling defoliating insects in China include aerial and ground application of chemical and biological insecticides, and mass rearing and release of fungi and parasitoids. In addition, investigations are underway for a cytoplasmic virus to control *D. punctatus* and the use of the predator *Rhizophagus grandis* for biological control of the bark beetle, *Dendroctonus valens**.

In Mongolia, continuous attempts have been made by the government to control outbreaks of the Siberian caterpillar, *Dendrolimus sibiricus**, and other defoliators but the vast areas, lack of trained personnel, limited facilities, financial constraints and poor equipment coupled with extreme weather events makes pest management a monumental task.

In India, most pest management tactics are aimed at planted forests and include a combination of biological, chemical and silvicultural methods primarily to manage defoliators of teak. A variety of fungicides have been used for disease control in nurseries in Indonesia and removing infested trees has helped to protect *Paraserianthes falcata* plantations from the stem borer *Xystrocera festiva*.

Ownership

Information on the capacity of private landowners in forest health protection is lacking. Although there are broad trends in the region towards more private ownership of forests (FAO, 2006a), forests are mostly state-owned in countries such as China and Mongolia. In Indonesia, some private plantation companies have organized research units that monitor and study forest pest and disease problems.

ADDITIONAL INFORMATION

In comparison to other regions, reporting on forest health issues for FRA 2005 was fairly complete for Asia and the Pacific, at least for mainland Asian countries. More than 10 million hectares of forest were reported to be affected by insect pests annually (average 1998–2002) and more than 9 million hectares by diseases (FAO, 2007a). It has been suggested that forest pests and other disturbances may have a more widespread impact than fire in this region (FAO, 2007a).

A number of forest pests reported from the profile countries are also significant pests in other countries of the region. A pest of planted forests in China, the Asian longhorned beetle, *Anoplophora glabripennis**, has increased in range as a result of widespread planting of susceptible poplar hybrids (EPPO, 1999). It is also believed to occur in the Democratic People's Republic of Korea and the Republic of Korea (EPPO, 1999). This pest has been introduced into other countries such as Canada and the United States through international trade. As a result, many countries in other regions have become increasingly concerned about this pest (EPPO, 1999), and this contributed to the international recognition of the importance of International Standards for Phytosanitary Measures (ISPMs), in particular guidelines for regulating wood packaging materials in international trade (ISPM No. 15).

Native to Indonesia and Papua New Guinea, the coconut leaf beetle, *Brontispa longissima*, is potentially one of the most serious insect pests of coconut and ornamental palm plants in Southeast Asia (APFISN, 2006). Recorded in China, Indonesia and Thailand, it is also known as a pest in Australia, Cambodia, Lao People's Democratic Republic, Malaysia, Maldives, Myanmar, Nauru, the Philippines, Singapore and Viet Nam (Rethinam and Singh, 2007). To address the rapid spread of this pest, APFISN organized a regional workshop in 2005 in Viet Nam to develop an Asia and Pacific strategy for forest invasive species with a focus on the coconut leaf beetle (FAO, 2007b). Participants shared information on risk assessment, monitoring and biological control measures for this significant pest.

The pine wood nematode, *Bursaphelenchus xylophilus**, causes a serious wilt disease in pines and other conifers. Recorded in China, the pest is also known to occur in Japan and the Republic of Korea; it is an introduced species of major global phytosanitary concern.

Occurring naturally in India, Myanmar, the Lao People's Democratic Republic and Thailand and planted in many countries, teak (*Tectona grandis*) is a very valuable forest tree in the Asia and the Pacific region. Several pest species cause significant economic losses. Some of the major indigenous teak pests include the leaf-feeding lepidopterans *Hyblaea puera* and *Eutectona machaeralis* and the stem borer *Xyleutes ceramica*. Reported in naturally regenerated and planted forests in India and Thailand, the teak skeletonizer, *Eutectona machaeralis*, is also an important invasive pest of teak in Bangladesh, Lao People's Democratic Republic, Myanmar, the Philippines and Sri Lanka (Nair, 2001; Leuangkhamma and Vongsiharath, 2005). The teak defoliator, *Hyblaea puera*, recorded in three of the selected countries (India, Indonesia and Thailand) is also a pest in Australia, Bangladesh, Cambodia, China, Fiji, Japan, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Papua New Guinea, the Philippines, Samoa, the Solomon Islands, Sri Lanka and Viet Nam (Nair, 2001; Chandrasekhar *et al*., 2005). A pest of naturally regenerated and planted forests, the beehole borer, *Xyleutes ceramica*, was recorded in Indonesia and Thailand and is also known to be a pest in Myanmar.

Indigenous *Dendrolimus* species are a significant problem for the region's forests. The defoliating caterpillar, *D. punctatus*, is a major pest of indigenous pine plantations in China and Viet Nam (FAO, 2001) while *D. tabulaeformis* infests China's naturally regenerated forests. The Siberian caterpillar, *D. sibiricus**, is a significant pest of larch and pines and serious outbreaks occur in China, the Democratic People's Republic of Korea, the Republic of Korea and Mongolia. Recently, the Democratic People's Republic of Korea has been experiencing outbreaks of *D. spectabilis* in coniferous forests and woodlands around Pyongyang and in North Hwanghae Province, affecting more than 100 000 ha of mainly naturally regenerated *Pinus densiflora*. Found also in China, Japan and the Republic of Korea, this pest is a significant defoliator of pines when outbreaks occur. Control options currently being investigated for this pest include the application of pheromones, egg parasitoids, and trunk banding.

The mahogany shoot borer, *Hypsipyla robusta**, reported above to attack several species of high quality timber in India, Indonesia and Thailand, has also been reported to cause damage in Australia, Bangladesh, Pakistan and Sri Lanka. In fact, it has been recorded in all Asia and Pacific countries where *Swietenia* species have been planted with the exception of some Pacific islands such as Fiji, eastern Solomon Islands, and Western Samoa (Nair, 2001).

Several species of *Lymantria* are pests including the ubiquitous Asian strain of *L. dispar*. *L. lepcha* is a pest of broadleaf trees in Indonesia in naturally regenerated forests, while India reported both *L. mathura* and *L. obfuscata* as pests of broadleaf trees in planted forests.

Bark- and wood-boring beetles of the genera *Ips*, *Tomicus* and *Xylosandrus* are important pests of forests in the region and were reported from four of the five countries in the analysis. The six-spined engraver beetle, *Ips sexdentatus**, and the larch bark beetle, *I. subelongatus**, were recorded as indigenous pests in Mongolia. Thailand also reported *I. sexdentatus* as a pest of planted conifers.

Two indigenous species of *Tomicus*, the lesser pine shoot beetle, *T. minor*, and the common pine shoot beetle, *T. piniperda*, are pests of conifers in Mongolia's naturally regenerated and planted forests. Recently, a newly introduced species of pine shoot beetle, *Tomicus* n.sp., has caused extensive mortality of Yunnan pines (*Pinus yunnanensis*) in the Yunnan Province of China, affecting over 200 000 ha of pine plantations (Sun *et al*., 2005).

Two indigenous *Xylosandrus* species were reported as pests of broadleaf planted forests. In particular, the black twig borer, *X. compactus*, was noted as a pest of *Swietenia macrophylla* in Thailand and the brown twig borer, *X. morigerus*, was reported as a pest in Indonesia.

Although not reported from the selected Asia and Pacific countries, a number of other pests pose considerable threats to forests in the region. These include the following.

- The European woodwasp, *Sirex noctilio**, is a significant pest of exotic pine plantations in the region, primarily in New Zealand and Australia, including Tasmania. Native to southern Europe and North Africa, this insect was probably introduced first into New Zealand on unprocessed pine logs imported from Europe (FAO, 2001).
- Believed to be native to Australia, the blue gum chalcid, *Leptocybe invasa**, is currently spreading through Africa, Europe and the Near East. A serious pest of young eucalypt trees and seedlings, it has been reported from Asia and the Pacific in Viet Nam and more recently in India (Jacob, Devaraj and Natarajan, 2007).
- The eucalyptus or guava rust, *Puccinia psidii*, is a serious threat to eucalypt plantations in many parts of the world, particularly in Australia where eucalypts are native. Considered a severe problem in its native region of Latin America and the Caribbean, there have also been unconfirmed reports of its occurrence in India. In 2004, APFISN, in collaboration with the Australian Centre for International Agricultural Research (ACIAR), the Asia-Pacific Forestry Commission (APFC) and FAO, organized a workshop on the development of an Asia-Pacific regional strategy for eucalyptus rust.
- The North American bark beetle, *Ips grandicollis,* was introduced into Australia where it attacks valuable planted forests of exotic pine species such as *Pinus elliottii*, *P. pinaster*, *P. taeda* and most importantly, *P. radiata* (FAO, 2001; EPPO/CABI, 1997).

REGIONAL PEST MANAGEMENT EFFORTS

Progress has been made in the region in strengthening institutions to support improved forest management, including forest health and protection. The Asia-Pacific Forest Invasive Species Network (APFISN), launched in 2004, focuses on technical and organizational issues to address the prevention, detection, management and control of forest invasive species in the region. National focal points play a key role in facilitating the exchange of information on forest invasive species among network members. Several mechanisms are in place to facilitate information exchange including a network Web site, newsletters and a regional forest invasive species listserver. The Chinese

Academy of Sciences has also begun work on developing a forest invasive species database which will provide a system for collating, storing and readily accessing information gathered by the network. The database will be further developed in collaboration with network members.

The Asia and Pacific Plant Protection Commission (APPPC) administers an intergovernmental treaty, the Plant Protection Agreement for the Asia and Pacific Region, and is an RPPO under the IPPC. Twenty-four countries are currently members of the Commission: Australia, Bangladesh, Cambodia, China, Democratic People's Republic of Korea, Fij, France (for French Polynesia), India, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, New Zealand, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Samoa (Western), Solomon Islands, Sri Lanka, Thailand, Tonga and Viet Nam.

Europe

The total number of pest species recorded from the three countries in the region was 44 (Figure 5).

Insect pests represented 86 percent of all the forest pests (Table 6). Diseases and other pests represented almost 7 percent each. The mammalian pests reported were from Moldova and included Sika deer (*Cervus nippon*), the fallow deer (*Dama dama*), and the raccoon dog (*Nyctereutes procyonoides*).

Indigenous pests were the most commonly reported, representing 89 percent of all pest species, while the remaining were introduced. All were recorded in naturally regenerated forests.

The majority of pest species were recorded in naturally regenerated forests (almost 62 percent) while almost 5 percent were found in planted forests. Moldova and Romania reported more pests in naturally regenerated forests while pests in the Russian Federation were found equally in both forest types. These findings are different than those in most other regions where more pests were recorded in planted forests.

About 50 percent of the pests were recorded on broadleaf tree species, and 43 percent on conifers. Moldova and Romania reported more pests on broadleaf trees while the Russian Federation reported more on conifers.

Lepidopteran species were the most frequently reported insect pests (Figure 6). Romania and the Russian Federation also reported a high number of coleopterans. Significant pests of pines, spruce and other conifers, *Ips acuminatus* and *I. amitinus,* were recorded in Romania's naturally regenerated forests. The large larch bark beetle, *I. cembrae*, was recorded in the naturally regenerated and planted forests of the Russian Federation. All pathogens reported were species from the phylum Ascomycota.

SPECIES FOUND IN MORE THAN ONE COUNTRY

Eleven pest species were recorded in more than one country in the region: ten insect pests and one disease (Table 7). Five of the transboundary pests were recorded in naturally regenerated forests and six in both planted and naturally regenerated forests. Six were recorded on broadleaf tree species, three on conifers and two on both host types.

Countries profiled in the region

Sixty percent of the transboundary insect pests were lepidopteran species. Two *Lymantria* species were reported from the region, both of which occurred in more than one country. The gypsy moth, *Lymantria dispar**, was reported to be found on both broadleaf and conifer trees in naturally regenerated forests in Moldova (European strain). Romania (European strain) and the Russian Federation (Asian strain) reported this pest in both forest types and both host types. *Lymantria monacha**, the nun moth, was reported on broadleaf and conifer trees in Romania's naturally regenerated forests and from the Russian Federation in both forest and host types.

FIGURE 5
Number of forest pest species reported, Europe

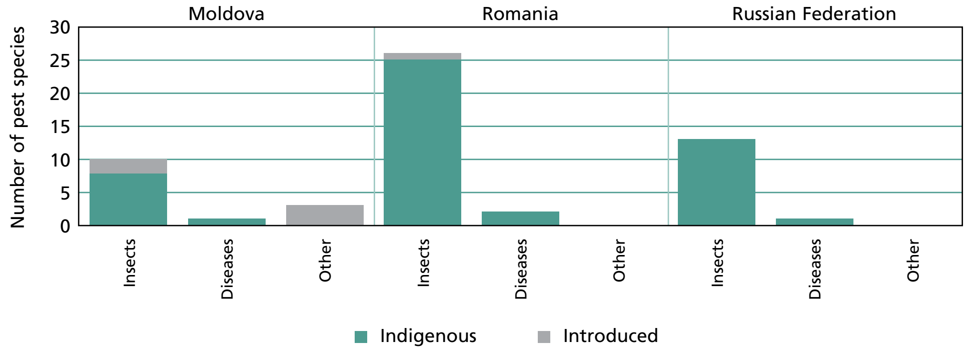
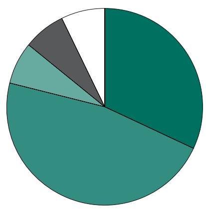


FIGURE 6
Most prevalent pests, Europe



Insects
- Coleoptera 32%
- Lepidoptera 47%
- Hymenoptera 7%

Diseases
- Ascomycota 7%

Other
- Other pests 7%

TABLE 6
Summary of the data on forest pest species reported, Europe

Pest Type	Number of pest species						
	Total	In naturally regenerated forests	In planted forests	In both types of forest	On broadleaf	On conifer	On both host types
Indigenous species							
Insects	36	21	2	13	15	18	3
Diseases	3	1	0	2	2	1	0
Other	0	0	0	0	0	0	0
Introduced species							
Insects	2	2	0	0	2	0	0
Diseases	0	0	0	0	3	0	0
Other	3	3	0	0	0	0	0
Total	**44**	**27**	**2**	**15**	**22**	**19**	**3**

Other lepidopterans included *Erannis defoliaria*, *Operophtera brumata*, *Tortrix viridana* and *Hyphantria cunea*. The mottled umber moth, *Erannis defoliaria*, the winter moth, *Operophtera brumata*, and the green oak tortix, *Tortrix viridana*, were all reported as indigenous pests of oak (*Quercus* spp.) in naturally regenerated forests in Moldova and Romania. The fall webworm, *Hyphantria cunea*, introduced from its native North America into Moldova and Romania where it attacks naturally regenerated broadleaf forests, is a tent-making defoliator of broadleaf trees and shrubs including *Betula*, *Salix*, *Prunus* and *Populus* spp.

The remaining transboundary insect pests were indigenous coleopteran species. The six-toothed bark beetle, *Ips sexdentatus**, and the European spruce bark beetle, *I. typographus**, are significant pests of conifers throughout the region, particularly pines and spruce respectively. They were reported in naturally regenerated forests in Romania and in both naturally regenerated and planted forests in the Russian Federation. Two indigenous *Tomicus* spp. (the lesser pine shoot beetle, *T. minor*, and the common pine shoot beetle, *T. piniperda)* are pests of conifers in Romania's naturally regenerated forests. The latter species was also recorded in both forest types in the Russian Federation. The weevil, *Stereonychus fraxini*, is a significant pest of ash (*Fraxinus excelsa*) in the region, reported from Moldova and Romania where it attacks naturally regenerated broadleaf forests.

One pathogen, *Microsphaera abbreviata*, was reported as a transboundary pest, recorded in naturally regenerated and planted broadleaf forests in Moldova and Romania.

TABLE 7
Species found in more than one country, Europe

Pest species	Order/phylum: family	Countries of occurrence	Type of forest	Host type
Insects				
Erannis defoliaria	Lepidoptera: Geometridae	Moldova, Romania	Naturally regenerated	Broadleaf
Hyphantria cunea	Lepidoptera: Arctiidae	Moldova, Romania	Naturally regenerated	Broadleaf
*Ips sexdentatus**	Coleoptera: Scolytidae	Romania, Russian Federation	Naturally regenerated, planted	Conifer
*Ips typographus**	Coleoptera: Scolytidae	Romania, Russian Federation	Naturally regenerated, planted	Conifer
*Lymantria dispar**	Lepidoptera: Lymantriidae	Moldova (European strain), Romania (European strain), Russian Federation (Asian strain)	Naturally regenerated, planted	Broadleaf, conifer
*Lymantria monacha**	Lepidoptera: Lymantriidae	Romania, Russian Federation	Naturally regenerated, planted	Broadleaf, conifer
Operophtera brumata	Lepidoptera: Geometridae	Moldova, Romania	Naturally regenerated	Broadleaf
Stereonychus fraxini	Coleoptera: Curculionidae	Moldova, Romania	Naturally regenerated	Broadleaf
Tomicus piniperda	Coleoptera: Scolytidae	Romania, Russian Federation	Naturally regenerated, planted	Conifer
Tortrix viridana	Lepidoptera: Tortricidae	Moldova, Romania	Naturally regenerated	Broadleaf
Diseases				
Microsphaera abbreviata	Ascomycota: Erysiphaceae	Moldova, Romania	Naturally regenerated, planted	Broadleaf

CAPACITY FOR FOREST HEALTH PROTECTION

Monitoring and detection

In Moldova and Romania, forest health conditions are regularly monitored and pests of special concern are monitored annually. Romania monitors specific pests such as nun moth, oak leaf roller, gypsy moth and bark beetles with pheromone traps. They also use sampling systems developed to predict damage by defoliators. In the Russian Federation, monitoring activities are typically carried out in areas of large outbreaks or those areas made susceptible to pests through abiotic factors such as pollution. Monitoring programmes have been carried out to target specific pests such as the defoliators *Lymantria dispar**, *L. mathura* and *L. monacha**.

Data management

Tools for data management in Moldova and Romania are available and apparently advanced, particularly in Romania. No information was provided on the capacity for data management in the Russian Federation.

Moldova and the Russian Federation provided data on the area affected by insects and/or diseases for FRA 2005 for both reporting periods: 1990 (annual average from 1988 to 1992) and 2000 (1998 to 2002). Moldova reported that 61 200 ha of forests were damaged by insects for the 1990 reporting period and 96 000 ha for 2000. The Russian Federation reported that insects affected over 1.7 million hectares for the 1990 reporting period and almost 5 million hectares for 2000, and that diseases impacted almost 125 000 ha (1990) and over 950 000 ha (2000).

Pest management

Typically pest management techniques such as ground and aerial application of biological or chemical insecticides are carried out in the face of major outbreaks of damaging forest pests. Romania, however, carries out preventative measures including encouragement of mixed species stands, maintenance of proper stocking levels, establishment of nesting sites for insectivorous birds and protection of predaceous ant nests.

Ownership

All lands are public in Moldova and the Russian Federation. In Romania, the independent autonomous forestry agency, RomSilva, conducts forest pest management activities on all forest lands. Private landowners are expected to cover costs associated with forest health activities.

ADDITIONAL INFORMATION

Compared to other regions, Europe has a great deal of information available on the impact of forest insect pests and diseases. For the 2000 reporting period for FRA 2005, Europe provided data on insect pests and diseases for over 90 percent of the region's forest area (FAO, 2006a). The annual average of forest area affected by insects for this period was 6.4 million hectares or 0.7 percent, while diseases affected 3.1 million hectares or 0.3 percent (FAO, 2007a). This marks a notable increase over the average area of forest impacted by insects and diseases in the 1990 period (FAO, 2006a), perhaps due to the increased susceptibility of forests and subsequent pest attacks following major storms in the region in December 1999.

Some of the pests recorded in selected countries are also found elsewhere in Europe. The oak processionary caterpillar, *Thaumetopoea processionea**, recorded as a pest in Romania, is a major pest of oak throughout Europe. Native to central and southern Europe where it is widely distributed, it has been expanding northwards, presumably in response to climate change, and is now firmly established in northern France and the Netherlands and has even been reported in southern Sweden. A related species, the pine processionary caterpillar, *Thaumetopoea pityocampa**, is considered one of the most important forest pests in the Mediterranean region and is commonly found in pine forests (EPPO/CABI, 1997). A marked change in distribution is also occurring related to climate shift and the insect pest is steadily moving north.

*Ips sexdentatus** occurs in *Pinus* forests throughout Europe and although it is considered a secondary pest by attacking stressed trees, it can kill trees of commercial importance (EPPO/CABI, 1997). *Ips typographus** is considered the most destructive species of the genus and probably the most serious pest of spruce in Europe (EPPO/CABI, 1997). It is common throughout the entire natural range of *Picea abies* in Europe and also occurs in plantations in Western Europe, outside the natural range of the host. Outbreaks have occurred in the Czech Republic, Germany, Italy, Norway, Poland and Sweden. In the mid to late 1990s, spruce stands in Slovakia also experienced a serious infestation of bark beetles (particularly *Ips typographus** and *Pityogenes chalcographus* but also *I. duplicatus*, *I. amitinus* and *Polygraphus polygraphus*) and fungal diseases (primarily *Armillaria* sp.) which caused the death of many trees, loss of timber and deterioration of the environment through poor management of infested trees.

Cyclical outbreaks of the gypsy moth, *Lymantria dispar**, occur in many countries in the region and cause considerable damage. FAO has provided emergency assistance to Bulgaria, Moldova and Romania to deal with outbreaks of this pest.

While not reported from the selected countries, *Phytophthora ramorum**, associated with sudden oak death and other diseases on broadleaf and conifer trees, is a major concern in the region. It has been found in Belgium, the Czech Republic, Denmark, France, Germany, Italy, the Netherlands, Norway, Ireland, Slovenia, Spain, Sweden and the United Kingdom (Kliejunas, 2005; DEFRA, 2005a). *P. ramorum* has mainly affected ornamental plant species in nurseries although it has been found on a few trees and in some established plantings of shrub hosts (mainly rhododendron) in some countries (DEFRA, 2005b). *P. kernovieae* is a new and potentially serious pathogen of woodland environments recently found in the UK, causing extensive leaf blight and dieback of rhododendron and large nectrotic cankers on beech trees. Symptoms progress rapidly, increasing the degree of risk (UK Forestry Commission, 2008; EPPO, 2008).

Another problem is the significant impact that many mammal species, such as squirrels, rabbits, deer and moose, have on European forests through browsing, overgrazing and stripping of bark. Heavy grazing can result in severe damage to trees in both naturally regenerated and planted forests and woodlands and can also prevent natural tree regeneration and reduce populations of ground cover and understorey species. Large herbivores also cause physical damage to trees by scraping tree trunks and destroying smaller saplings with their antlers. In Sweden, for example, dense populations of moose and roe deer are known to cause severe damage, particularly in pine and hardwood plantations and young forests, although the level of damage varies considerably (Swedish Forest Agency, 2007).

Severe storms, particularly those in 1990, 1999/2000, 2004/05 and January 2007, have had catastrophic impacts on forests in the region (UNECE Timber Committee, n.d.). Impacts can be observed for years after the storm has occurred. In addition to damaging considerable areas of forest, such storms have also made them more susceptible to forest pest outbreaks. Windblown wood presents ideal conditions for massive fires and insect outbreaks, threatening forests not directly damaged by the storms themselves. Not only are the fallen trees at risk, but the adjacent trees can serve as hosts for the pests as well.

The 1999/2000 storms were centred on Denmark, France, Germany, Sweden and Switzerland but countries across Europe sustained damage to their forests. Denmark, Sweden and Slovakia suffered much damage in the 2004/05 storms and the 2007 storms impacted Belgium, the Czech Republic, Denmark, France, Germany, Sweden and the United Kingdom. In Sweden much of the storm-felled trees are within areas already at high risk of large-scale outbreaks of the European spruce bark beetle, *Ips typographus** (Swedish Forest Agency, 2007). Newly storm- and wind-felled trees in Finland have also been a prime target for *I. typographus* which reproduces in such damaged trees (Erikssona, Pouttub and Roininena, 2005).

Forest pests newly introduced to the region include the citrus longhorned beetle, *Anoplophora chinensis* (Coleoptera: Cerambycidae), the blue gum chalcid, *Leptocybe invasa**, the Asian longhorned beetle, *Anoplophora glabripennis**, the oriental chestnut gall wasp, *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae), and chestnut blight, *Cryphonectria parasitica* (Ascomycota: Cryphonectriaceae).

Originating in Japan and Korea where it is a serious pest of deciduous tree species and citrus, *A. chinensis* was added to the EPPO A1 List in 1994 (listed as *A. malasiaca*). The beetle was first discovered in Europe in 2000 at Parabiago, Italy. Despite the application of control techniques, this pest has since spread into nearby villages. Single occurrences were recorded in 2003 in the Netherlands and France but the pest was officially declared eradicated in 2006. It was found in Switzerland in 2006 but the two infested *Acer* spp. trees were destroyed. European interceptions have included infested bonsai trees from Japan and potted plants (*Acer* spp.) from China, both of which are critical pathways (EPPO, personal communication, 2008). The potential impact on the region has not yet been determined.

Believed native to Australia, the blue gum chalcid, *Leptocybe invasa**, is currently spreading through Africa, Europe and the Near East. A serious pest of young eucalypt trees and seedlings, it has been reported in Mediterranean countries, including France, Italy, Portugal and Spain, where eucalypts are widely grown for forestry and ornamental purposes (EPPO, 2008).

*Anoplophora glabripennis** was added to the EPPO A1 list after a pest risk assessment by the Panel on Phytosanitary Regulations in 1999 considered the risk of its establishment in Europe to be high. It has been recorded in Austria (2001), France (2003), Germany and Poland (2004) and Italy (2007). To date there has been no establishment recorded in Europe.

The oriental chestnut gall wasp, *Dryocosmus kuriphilus*, was added to the EPPO A2 list after being discovered in the southern part of the Piemonte region of Italy, where management attempts include classical biological control. This wasp is a serious pest of chestnut worldwide with a high potential for spread throughout the region through female flight and movement of infested chestnut plants and plant materials.

Native to Asia, chestnut blight, *Cryphonectria parasitica*, was first discovered in 1938 in Europe in northern Italy. Since then the fungus has spread rapidly throughout much of southern and Central Europe where chestnuts are cultivated and has been recorded in Austria, Belgium, Bosnia and Herzegovina, Croatia, France, Germany, Greece, Hungary, Montenegro, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain, Switzerland, the former Yugoslav Republic of Macedonia, Turkey and Ukraine (EPPO, 1997).

The emerald ash borer, *Agrilus planipennis**, has recently been reported in the Russian Federation, both European and Asiatic (Y. Baranchikov, personal communication). Native to eastern Asia, this pest is a major threat to ash trees and poses a potential threat to European forests.

Recent introductions of the pine wilt nematode, *Bursaphelenchus xylophilus**, the causal agent of pine wilt disease, has resulted in severe losses to *Pinus pinaster* in Portugal. The nematode and vector *M. galloprovincialis* now co-exist, and other susceptible pines are now at risk in areas above 20 °C. If this pest spreads to the rest of Europe, it could pose a threat to European forestry and trade.

REGIONAL PEST MANAGEMENT EFFORTS

A number of organizations exist at the regional level to aid in the monitoring and detection of plant and forest pests. The European and Mediterranean Plant Protection Organization (EPPO) is an intergovernmental organization responsible for European cooperation in plant health. Founded in 1951 by 15 European countries, EPPO now has 48 members, covering almost all countries of the European and Mediterranean region. Its objectives are to protect plants, to develop international strategies against the introduction and spread of dangerous pests and to promote safe and effective control methods. As a Regional Plant Protection Organization (RPPO) under the IPPC, EPPO participates in global discussions on plant health organized by the FAO and the IPPC Secretariat.

Since the 1970s, EPPO has maintained a list of A1 (absent from region) and A2 (present in region) quarantine pests, based on technical justification and a meticulous approval procedure. The purpose of the lists is to recommend that organisms of serious phytosanitary concern be regulated as quarantine pests. In 2004 a list of invasive plants was created to draw attention to plant species that pose a threat to plant health, environment and biodiversity in the region. An Action List was added in 2005 to draw attention to recently added pests recommended for regulation or those that present an urgent phytosanitary concern. EPPO also produces a large number of standards and publications on plant pests (including many which impact forests), phytosanitary regulations, and plant protection products.

Long-term monitoring and data collection is fairly well-established in the region as a whole. The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was created in 1985 under the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution (LRTAP) in response to growing public awareness of the possible adverse effects of air pollution on forests. In cooperation with the European Union, ICP Forests monitors forest conditions in Europe using two different monitoring intensity levels. Annual transnational surveys of forest conditions have been conducted by means of large-scale monitoring of tree vitality of 6 000 observation plots with about 130 000 sample trees on a systematic transnational grid of 16 x 16 km throughout the region. The intensive monitoring level involves the assessment of crown condition, increment, chemical composition of foliage and soils and other variables on approximately 800 permanent observation plots established across Europe.

The Ministerial Conference for the Protection of Forests in Europe (MCPFE) is a high-level cooperation of 46 European countries and the European Community that addresses the most important issues on forests and forestry and makes recommendations related to the protection and sustainable management of forests in Europe. The MCPFE has adopted the Pan-European Criteria and Indicators for Sustainable Forest Management to help define and monitor the region's forests. The quantitative indicators of forest health and vitality include changes in defoliation and serious damage caused by biotic or abiotic agents, including insects and diseases.

Latin America and the Caribbean

The total number of pests for the eight countries in the region was 113 (Figure 7). Insect pests comprised 77 percent of all pests reported, pathogens 11 percent and other pests 11 percent (Table 8). The other pest category included goat (*Capra hircus*), Canadian beaver (*Castor canadensis*), European rabbit (*Oryctolagus cuniculus*), brown capuchin monkey (*Cebus paella*), red deer (*Cervus elaphus*), guanaco (*Lama guanicoe*), Cape hare (*Lepus capensis*), nematode (*Subanguina chilensis*), desert spider mite (*Tetranychus desertorum*) and species of the mistletoe genera *Arceuthobium*, *Misodendrum*, *Phoradendron* and *Psittacanthus*.

Significantly more pest species were recorded in planted forests than in naturally regenerated forests. Forest pests were reported almost equally from broadleaf and conifer tree species. The pests were almost evenly split between indigenous and introduced species. Considerably more introduced pests were reported from planted forests.

Countries profiled in the region

Note: For the purposes of this study, Mexico has been included within Latin America and the Caribbean.

Coleoptera and Hemiptera were the most represented insect pest orders reported from almost all countries (Figure 8). The only exception was Colombia which reported a majority of lepidopteran pests. The majority of pathogens reported from the selected countries were Ascomycota species. Mistletoes (Santalales) were the most commonly reported of the other pest species followed by even-toed ungulates (Artiodactyla).

FIGURE 7
Number of forest pest species reported, Latin America and the Carribean

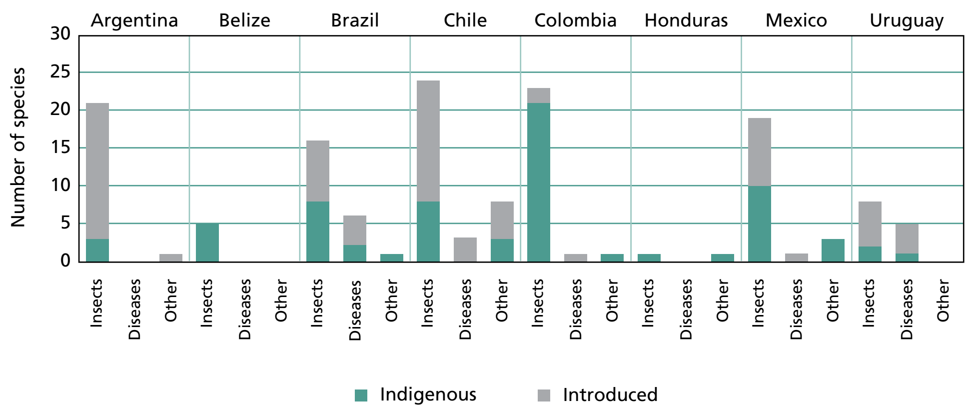
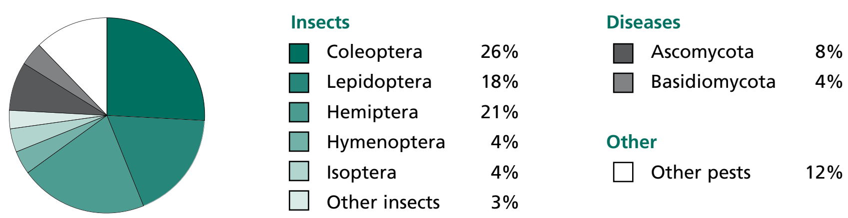


TABLE 8
Summary of the data on forest pest species, Latin American and Caribbean

Pest Type	Number of pest species						
	Total	In naturally regenerated forests	In planted forests	In both types of forest	On broadleaf	On conifer	On both host types
Indigenous species							
Insects	47	21	25	1	25	17	5
Diseases	2	0	2	0	1	1	0
Other	8	6	2	0	4	2	2
Introduced species							
Insects	40	1	33	6	13	25	2
Diseases	11	0	11	0	7	3	1
Other	5	4	1	0	2	0	3
Total	**113**	**32**	**74**	**7**	**52**	**48**	**13**

FIGURE 8
Most prevalent pests, Latin America and Caribbean



SPECIES FOUND IN MORE THAN ONE COUNTRY

Eight of the transboundary pests recorded in the region were of the order Hemiptera (Table 9), mostly in coniferous forests. *Ctenarytaina eucalypti* and *Glycaspis brimblecombei* were reported in planted broadleaf forests, the former in Chile, Colombia and Uruguay and the latter in Brazil, Chile and Mexico.

Aphids (*Cinara* spp.) are major pests of conifers. Fifteen species were reported, five of which occurred in more than one country (Table 9). *Cinara acutirostris*, *C. cedri*, *C. costata*, *C. juniperi*, *C. maghrebica*, *C. piceae* and *C. pilicornis* were all recorded as pests in Argentina's planted forests. *Cinara atlantica* and *C. piniformosana* were reported in planted pine forests in Brazil and *C. cupressi* was recorded in Chile's naturally regenerated forests. Both *Cinara maritimae* and *C. pinivora** were noted as pests of planted pine forests in Argentina and Brazil. Naturally regenerated forests in Chile and planted forests in Argentina and Brazil were affected by both *Cinara fresai* and *C. tujafilina*.

Pine needle aphids (*Eulachnus* spp.) are found in Argentina, Chile and Colombia. *Eulachnus rileyi* infests planted forests in Argentina and Chile and both forest types in Colombia. Argentina also reported *E. tauricus* as a pest of planted forests.

The Coleoptera species reported included *Dendroctonus frontalis** as well as two pests of broadleaf trees: *Megaplatypus mutatus*, recorded in both naturally regenerated and planted forests in Argentina, Brazil, and Uruguay; and the eucalyptus longhorned borer, *Phorocantha recurva**, a major pest of planted forests in Chile and Uruguay.

Dendroctonus species are significant pests of conifers in naturally regenerated forests. Four species were recorded from the selected countries including one transboundary pest. *Dendroctonus adjunctus*, *D. mexicanus* and *D. pseudotsugae* were recorded from Mexico. The southern pine beetle, *Dendroctonus frontalis**, is a major pest in the region, reported from Belize (note the taxonomy is under review), Honduras and Mexico.

The lepidopteran pests included *Hypsipyla grandella**, *Rhyacionia buoliana* and *Sarsina violascens*. The mahogany shoot borer, *Hypsipyla grandella*, is indigenous to the region and was the most widespread pest. It was reported as a pest of planted broadleaf forests in Argentina, Belize, Brazil, Colombia, Mexico and Uruguay. Argentina and Chile reported the European pine shoot moth, *Rhyacionia buoliana*, as a major pest of planted pines. *Sarsina violascens* was reported as a pest of planted broadleaf forests, primarily attacking eucalypt species, in Argentina, Brazil and Mexico.

Three Hymenoptera species were reported from more than one country. Most notable is the European woodwasp, *Sirex noctilio**, which has caused significant damage to planted conifer forests in Argentina, Brazil, Chile and Uruguay. In Argentina and Chile, *Urocerus gigas* also attacks planted conifer forests, primarily Monterey pine, *Pinus radiata*. *Nematus desantisi* is a major pest of planted forests of *Salix* and *Populus* spp. in Argentina and Chile.

Numerous *Ips* species were recorded from the naturally regenerated pine forests of Belize and Mexico. *Ips calligraphus*, *I. grandicollis* and *I. apache* were reported as pests in Belize and *I. confusus* and *I. pini* were recorded from Mexico.

Three transboundary pathogens were reported from planted broadleaf forests in the selected countries. *Chrysoporthe cubensis** (formerly *Chryphonectria cubensis*) is known to kill significant numbers of eucalypts in Brazil and Colombia, particularly those in young plantations. *Ceratocystis fimbriata* and *Puccinia psidii* are also major pests of eucalypts in Brazil and Uruguay.

The beaver, *Castor canadensis*, and the parrot-flower mistletoe, *Psittacanthus* spp., were the other two transboundary pests recorded in the Latin American and Caribbean countries. Intentionally introduced into Argentina in 1947 for the fur industry, beavers are now having a significant impact on the structure of riparian forests in both

TABLE 9
Species in more than one country, Latin America and Caribbean

Pest species	Order/phylum: family	Countries of occurrence	Type of forest	Host type
Insects				
*Cinara cupressivora**	Hemiptera: Aphididae	Chile, Colombia	Naturally regenerated, planted	Conifer
Cinara fresai	Hemiptera: Aphididae	Argentina, Brazil, Chile	Naturally regenerated, planted	Conifer
Cinara maritimae	Hemiptera: Aphididae	Argentina, Brazil, Chile	Planted	Conifer
*Cinara pinivora**	Hemiptera: Aphididae	Argentina, Brazil	Planted	Conifer
Cinara tujafilina	Hemiptera: Aphididae	Argentina, Brazil, Chile	Naturally regenerated, planted	Conifer
Ctenarytaina eucalypti	Hemiptera: Psyllidae	Chile, Colombia, Uruguay	Planted	Broadleaf
*Dendroctonus frontalis**	Coleoptera: Scolytidae	Belize, Honduras, Mexico	Naturally regenerated	Conifer
Eulachnus rileyi	Hemiptera: Aphididae	Argentina, Chile, Colombia	Naturally regenerated, planted	Conifer
Glycaspis brimblecombei	Hemiptera: Psyllidae	Brazil, Chile, Mexico	Planted	Broadleaf
*Hypsipyla grandella**	Lepidoptera: Pyralidae	Argentina, Belize, Brazil, Colombia, Mexico, Uruguay	Planted	Broadleaf
Megaplatypus mutatus	Coleoptera: Platypodidae	Argentina, Brazil, Uruguay	Naturally regenerated, planted	Broadleaf
Nematus desantisi	Hymenoptera: Tenthredinidae	Argentina, Chile	Planted	Broadleaf
*Phorocantha recurva**	Coleoptera: Cerambycidae	Chile, Uruguay	Planted	Broadleaf
Rhyacionia buoliana	Lepidoptera: Tortricidae	Argentina, Chile	Planted	Conifer
Sarsina violascens	Lepidoptera: Lymantriidae	Argentina, Brazil, Mexico	Planted	Broadleaf
*Sirex noctilio**	Hymenoptera: Siricidae	Argentina, Brazil, Chile, Uruguay	Planted	Conifer
Urocerus gigas	Hymenoptera: Siricidae	Argentina, Chile	Planted	Conifer
Diseases				
Ceratocystis fimbriata	Ascomycota: Ceratocystidaceae	Brazil, Uruguay	Planted	Broadleaf
*Chrysoporthe cubensis**	Ascomycota: Incertae sedis	Brazil, Colombia	Planted	Broadleaf
Puccinia psidii	Basidiomycota: Pucciniaceae	Brazil, Uruguay	Planted	Broadleaf
Other				
Castor canadensis	Rodentia: Castoridae	Argentina, Chile	Naturally regenerated	Broadleaf
Psittacanthus spp.	Santalales: Loranthaceae	Honduras, Mexico	Naturally regenerated	Broadleaf, Conifer

Argentina and Chile (FAO, 2007a). They fell many trees, and their dams result in flooding of *Nothofagus pumilio* forests, effectively killing the trees. In 2007 they swam across the Magellan Straits from Tierra del Fuego and are now establishing in one of the national parks near Punta Arenas in Chile. Reported from both Honduras and Mexico, *Psittacanthus* spp. can affect the health and vitality of host trees through growth loss, reduction in seed production and, in extreme cases, tree mortality.

CAPACITY FOR FOREST HEALTH PROTECTION

Monitoring and detection

In many of the countries, monitoring and detection activities are an informal process of field surveillance by foresters and forest workers, often carried out only in planted forests. Belize, Brazil, Chile, Honduras and Mexico carry out aerial and ground surveys to detect and assess the damage caused by specific pests.

Data management

For the most part, information on pests and pest damage in the selected countries is qualitative. When quantitative data exist, they are not available in an easily accessible format. In some countries, such as Brazil, Colombia and Honduras, data management systems have been developed as part of programmes to address specific forest pests. Uruguay has developed a national database for all pest problems that could act as a model for the region.

Consistent data on the impacts of forest pests and diseases over time are not available for Latin America and the Caribbean (FAO, 2006a). As part of the FRA 2005 process, only five of the eight countries provided some quantitative data on forest pests; no data were reported from Argentina, Colombia and Uruguay. Bark beetles were noted to have damaged approximately 70 percent of forests in the Mountain Pine Ridge Forest Reserve in Belize. Brazil reported that 50 000 ha of forest were damaged by insects for the 1990 reporting period, and 30 000 ha of forest were affected by insects and 20 000 ha by diseases for the 2000 reporting period. In Chile, insects affected 866 000 ha and 531 000 ha for the 1990 and 2000 reporting periods respectively. Diseases impacted 13 000 ha and 810 000 ha for the two reporting periods. Insects, primarily bark beetles, damaged almost 550 ha (2000) of forest in Honduras. Mexico reported over 8 000 ha and over 7 800 ha of forest damaged by insects for the 1990 and 2000 reporting periods respectively. Diseases impacted 11 000 ha and 2 000 ha of forest for the two reporting periods.

Pest management

A variety of pest management techniques from physical management to biopesticides have been used in the selected countries, primarily to deal with specific pests in planted forests and reserves. Preventative measures, such as thinning and removal of susceptible trees, and direct control methods, such as salvage removal, cut and leave and burning of infested trees, have been applied in Belize, Honduras and Mexico to address outbreaks of *Dendroctonus frontalis** and other bark beetles. The introduction and release of parasitoids has been applied in many countries against pests such as *Cinara pinivora**, *Rhyacionia buoliana* and *Sirex noctilio**.

Ownership

For the most part, private landowners and forest companies have active programmes to protect planted forests from insect pests and diseases and may bring in international experts for consultation. In countries such as Chile, Honduras and Mexico, private companies and the government work in collaboration on issues of forest health. No information was found for Argentina and Belize where the majority of forests are in the public domain.

ADDITIONAL INFORMATION

Many countries in the region recognize environmental and forest health issues. However, consistent data over time are not available with enough reliability to draw conclusions about trends in forest health in Latin America and the Caribbean.

In Central America and Mexico, the indigenous *Dendroctonus* species has been credited with the greatest losses of pine forests in Central America in the past 40 years (Vité *et al*., 1975; Billings and Schmidtke, 2002). A regional bark beetle strategy has been prepared to address this pest.

The mahogany shoot borer, *Hypsipyla grandella**, continues to be a major problem throughout the region particularly in mahogany plantations (*Swietenia macrophylla*, *S. mahagoni*). Attempts to establish plantations of mahogany and other forest trees such as cedar (*Cedrela odorata*) and crabwood (*Carapa guianensis*) have failed in Belize, Dominica, Grenada, St. Lucia and St. Vincent because of the damage caused by this pest (Cock, 1985).

In 1995, the pink or hibiscus mealybug (*Maconellicoccus hirsutus*) was introduced in Grenada where it attacked teak (*Tectona* spp.) and Blue Mahoe (*Hibiscus elatus*) plantations but the damage was less severe than initially thought and the pest was controlled biologically by introducing a predatory wasp (C. Eckelmann, personal communication). The pest was subsequently introduced in Trinidad and Tobago, St. Kitts-Nevis and other eastern Caribbean islands. This insect is capable of feeding on 125 to 150 different plant species, posing a severe threat to natural mixed tropical forests as well as vegetable crops and ornamental plants in the region (FAO, 2001).

Hurricanes are a regular occurrence in the region, particularly in Central America and the Caribbean, and the impacts can be devastating. In areas where the centre of the storm passes, entire forests can be blown down, trees uprooted or damaged. Following a hurricane, forests can become more susceptible to forest pests, diseases and other problems such as vines. Forest fires, especially in semi-evergreen and dry forest types, are also a problem in the region and increase the susceptibility of forest trees to attack by insect pests and diseases.

REGIONAL PEST MANAGEMENT EFFORTS

IPPC regional plant protection organizations that help prevent the spread and introduction of pests and promote appropriate control measures include: Comité de Sanidad Vegetal del Cono Sur (COSAVE), Comunidad Andina (CA), Caribbean Plant Protection Commission (CPPC) and Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA).

Following the discovery of *Sirex noctilio** in Uruguay in 1986 and its spread to Argentina, Brazil and Chile, these countries agreed to work together to combat pests that affect regional trade. In 2008, with the assistance of FAO, these countries, together with Paraguay and Bolivia, established a network for integrated and dynamic forest pest management in the Southern Cone, Red de Países del Cono Sur sobre Especies Exoticas Invasoras a Ambientes Forestales (www.fao.org/forestry/52502).

Near East

The total number of pest species reported for the two countries in the Near East region was 81. Only seven pests were recorded for Cyprus while 75 were reported for Kyrgyzstan (Figure 9).

Insect pests were the most commonly reported pest species (70 percent) followed by diseases (15 percent) and other pests (15 percent) (Table 10). Kyrgyzstan reported 12 species in the other pest category, including the indigenous dwarf mistletoe (*Arceuthobium oxycedri*), while the remainder were acrarines. Both countries reported more indigenous species as forest pests.

Kyrgyzstan reported more pests in naturally regenerated forests, mainly on broadleaf trees, while pests in Cyprus were reported in equal numbers in naturally regenerated and planted forests, generally on conifers.

Of the insect pests, coleopterans were the most abundant species (Figure 10). Pathogens were only reported from Kyrgyzstan and the most common species reported were Basidiomycota.

Countries profiled in the region

FIGURE 9
Number of forest pest species reported, Near East

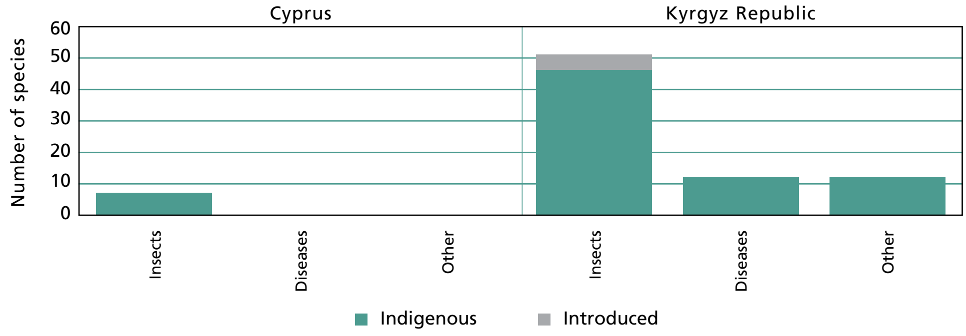
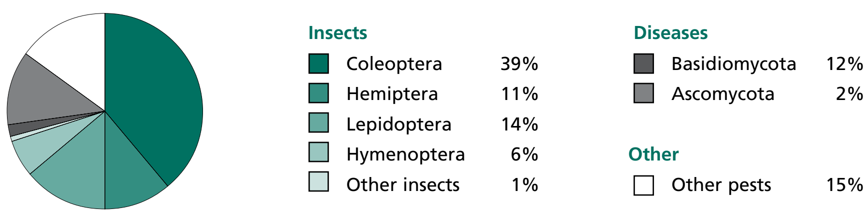


TABLE 10
Summary of the data on forest pest species reported, Near East

Pest Type	Number of pest species						
	Total	In naturally regenerated forests	In planted forests	In both types of forest	On broadleaf	On conifer	On both host types
Indigenous species							
Insects	52	26	16	10	25	25	2
Diseases	12	5	5	2	5	7	0
Other	12	8	4	0	11	1	0
Introduced species							
Insects	5	2	1	2	5	0	0
Diseases	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
Total	**81**	**41**	**26**	**14**	**46**	**33**	**2**

FIGURE 10
Most prevalent pests, Near East



SPECIES FOUND IN MORE THAN ONE COUNTRY

The gypsy moth, *Lymantria dispar**, was noted to occur in both countries; the Asian strain in Kyrgyzstan and the European strain in Cyprus. It is a major pest of broadleaf trees in both naturally regenerated and planted forests and is of particular concern in wild pistachio (*Pistacia Vera*), fruit trees and walnut (*Juglans regia*) forests in Kyrgyzstan. The indigenous bark beetles, such as *Ips*, *Orthotomicus* and *Tomicus* species, are a particular problem in the region.

CAPACITY FOR FOREST HEALTH PROTECTION

Monitoring and detection

As in other regions profiled, monitoring and detection activities in the Near East countries are often informal although some activities have targeted specific pests. In Cyprus, a method to predict defoliation by the pine processionary caterpillar, *Thaumetopoea wilkinsoni*, using egg mass and colony counts has been developed. Kyrgyzstan has a risk rating system for phytophagous insect pests.

Data management

National capacity for the collection and management of forest health data is weak in both the countries profiled. Little data are collected and tools for data management need to be developed. In Kyrgyzstan, a number of studies have been carried out on insect pests and a few on forest diseases.

No quantitative information was provided by Cyprus for FRA 2005. Kyrgyzstan provided information for both reporting periods. Insects affected 70 000 ha of forest for the 1990 period and 60 000 ha for the 2000 reporting period. Diseases affected 16 000 ha and 10 000 ha of forest for the 1990 and 2000 reporting periods respectively.

Pest management

In Cyprus, a variety of tactics have been used to target specific pests. Rapid removal of wind thrown, storm damaged or infested trees has been used to deal with bark beetle infestations. Direct control projects against the pine processionary caterpillar, *Thaumetopoea wilkinsoni*, have been conducted annually through ground or aerial application of microbial or chemical insecticides. No information was found on pest management strategies in Kyrgyzstan although the country correspondent noted that new control methods will be introduced, with priority given to biological control.

Ownership

Forests in Kyrgyzstan are public lands. In Cyprus private forest ownership is often passive, with little or no management.

ADDITIONAL INFORMATION

Insect pests, along with fire, are the greatest threats to forests in the Near East (FAO, 2007a). However, data are not highly reliable since most countries do not maintain good records on forest disturbances.

A number of important, high-profile pests are significant pests in the region including *Armillaria mellea**, *Erannis defoliaria*, *Hyphantria cunea*, *Lymantria dispar**, *Pineus pini*, *Thaumetopoea wilkinsoni** and *Thaumetopoea pityocampa**. In northern Iraq and southwestern Islamic Republic of Iran, brown-tail moth, *Euproctis melania*, is one of the most destructive defoliators of oak and fruit trees. In Lebanon, *Cedrus libani* was under serious threat from repeated defoliations caused by a new pest, the cedar web-spinning sawfly, *Cephalcia tannourinensis.* Fortunately, concerted efforts in management reduced the risk to local trees and gene stock and prevented transboundary spread. The blue gum chalcid, *Leptocybe invasa**, was reported in nurseries and young eucalypt plantations in Tunisia in 2004 (Ben Jamaa and Belhaj Salah, 2007).

Pines are the target of a variety of bark beetles that can cause tree death, branch dieback and reduced productivity. These include the European bark beetle, *Orthotomicus erosus**, in Cyprus and Turkey on *Pinus brutia* and *P. pinaster*; the lesser pine shoot beetle, *Tomicus minor*, found infesting *P. pinaster* in Cyprus and Turkey; the pine shoot beetle, *Tomicus destruens*, recorded in Cyprus; and *Phloeosinus armatus* recorded on *Cupressus sempervirens* in Cyprus. Currently, stands of *Pinus pinea* in Lebanon are seriously infested with an unidentified bark beetle; it may be a *Tomicus* species. Tree death has occurred in all stands.

Chestnut blight caused by the fungal pathogen *Cryphonectria parasitica* is a prevalent problem in *Castanea sativa* in chestnut-growing regions of Turkey.

Dieback and declines of forest trees, junipers and cedars in particular, are also a significant concern to many countries in the region. The interrelated causes, biotic and abiotic, are being examined. Some species affected by decline and dieback include: *Juniperus procera* in the Asir highlands, Saudi Arabia; *Cedrus libani, Juniperus excelsa* and *Abies cilicica* in Lebanon; and *Juniperus polycarpus* in Kyrgyzstan and Oman.

Phloeosinus armatus was recorded as a pest of conifers, cypress in particular, in naturally regenerated and planted forests in Cyprus. Kyrgyzstan reported *Phloeosinus turkestanicus* as a pest of conifers, primarily junipers, in both forest types.

REGIONAL PEST MANAGEMENT EFFORTS

Concerned about the increased threat to forests and trees outside forests posed by climatic changes that may influence movement and establishment of new insect pests and diseases, the countries of the region have established the Near East Network on Forest Health and Invasive Species (NENFHIS) (www.fao.org/forestry/51295) to foster integrated and dynamic forest pest management in the region and provide decision-makers with baseline data for making informed decisions.

North America

A variety of indigenous and introduced insect pests and diseases are known to negatively affect North American forests. No countries were profiled in this region, but the following is a brief discussion of some of the major pests impacting Canada and the United States.

INDIGENOUS INSECTS

Three species of Coleoptera (the southern pine beetle, mountain pine beetle and white pine weevil) are known pests of pines in the region. The southern pine beetle (*Dendroctonus frontalis**) is a very destructive pest of pines in the southern United States as well as Mexico and Central America (Billings *et al*., 2004). Populations can build rapidly to outbreak proportions and kill large numbers of trees. This beetle kills trees by a combination of girdling during construction of egg galleries and the introduction of blue stain fungi of the genus *Ophiostoma* (Billings *et al*., 2004).

The mountain pine beetle (*Dendroctonus ponderosae**) is the most destructive pest of mature lodgepole pine (*Pinus contorta*) forests in North America. In the western United States, outbreaks have been increasing in area after several years of drought (Tkacz, Moody and Villa Castillo, 2007). A major epidemic of this pest has been ongoing in western Canada (British Columbia and, more recently, Alberta) for several years and even with large-scale efforts to mitigate the impacts of the pest, millions of trees have been killed. The problem has been exacerbated by local climatic changes and increased winter temperatures which reduce mortality of overwintering stages. A record 10 million hectares of pines were recorded as infested during 2007 aerial overview surveys in British Columbia, with more than 860 000 ha of this located in provincial parks and protected areas (Westfall and Ebata, 2008). In January 2007, the Government of Canada announced the Mountain Pine Beetle Program, a three-year programme aimed primarily at slowing the eastward spread of the mountain pine beetle infestation, but also at recovering economic value from damaged forests and protecting forest resources and communities.

The white pine weevil (*Pissodes strobi*) is the most serious and economically important insect pest of spruce and pine species, primarily eastern white pine (*Pinus strobus*), in Canada and the United States (PFC and LFC, 2007). The weevil is also known to attack Norway spruce (*Picea abies*) and jack pine (*Pinus banksiana*) and, to a lesser extent, pitch pine (*P. rigida*), red pine (*P. resinosa*), Scots pine (*P. sylvestis*) and red spruce (*Picea rubens*).

Important indigenous lepidopteran defoliators in the region include the hemlock looper, forest tent caterpillar, large aspen tortrix, spruce budworm and western spruce budworm. Larvae of the hemlock looper (*Lambdina fiscellaria*) can be extremely destructive to hemlock (*Tsuga* spp.), balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*). It feeds on eastern hemlock (*T. canadensis*) in western areas of its distribution and on balsam fir in the east; during periodic outbreaks it will feed on other conifers and hardwoods.

The forest tent caterpillar (*Malacosoma disstria*) is a serious defoliator of trembling aspen (*Populus tremuloides*) and other hardwood tree species in Canada and the United States. Outbreaks occur periodically over wide areas of the eastern half of North America, resulting in inhibited growth and dieback. However, trees are seldom killed unless they sustain three or more successive years of complete defoliation (Cerezke, 1991).

The large aspen tortrix (*Choristoneura conflictana*) is an early summer defoliator of trembling aspen (*P. tremuloides*). While it does not generally affect tree survival, outbreaks may sometimes last for more than three years and can kill trees, particularly if trees are stressed by other factors such as drought (CFS, 2006a). Outbreaks of the pest occur periodically, impacting hundreds of square kilometres of aspen forests, often in association with infestations of the forest tent caterpillar (Cerezke, 1992).

Spruce budworm (*Choristoneura fumiferana*) and the western spruce budworm (*Choristoneura occidentalis*) are widespread destructive pests of spruce and fir species in many northern coniferous forests (CFS, 2006a). During years of peak infestation, over 20 million hectares of forest in Canada have been affected by *C. fumiferana* annually (Tkacz, Moody and Villa Castillo, 2007). Damage caused by *C. occidentalis* in British Columbia has increased steadily from over 120 000 ha of forests in 2001 to over 600 000 ha in 2004 (CFS, 2006a).

The hymenopteran balsam fir sawfly (*Neodiprion abietis*) is a common and destructive native defoliator that feeds mainly on balsam fir (*Abies balsamea*) and occasionally on white spruce (*Picea glauca*) and black spruce (*P. mariana*) (CFS, 2006a). Outbreaks occur occasionally and may cause growth loss or limited tree mortality.

Some indigenous pests may not have significant impacts on the region's forest resources but concerns about introductions into other nations can have serious effects on the forest sector through international trade restrictions. An example is the pine wilt nematode, *Bursaphelenchus xylophilus**, the causal agent of pine wilt disease, which is spread through insect vectors, pine sawyer beetles (*Monochamus* spp.). The pine wild nematode is native to North America, where it is widespread in natural coniferous forests, but significant losses have not been recorded and it is not considered a serious pest (EPPO/CABI, 1997). While the nematode has been associated with the death of some pines in the United States, in general losses are most often confined to non-native tree species (primarily *Pinus sylvestris*) in artificial forest ecosystems such as ornamental conifer plantings, windbreaks and Christmas tree plantations (EPPO/CABI, 1997; Liebhold *et al*., 1995).

While not a serious problem in North America, pine wilt disease is a major threat to Asian and European pine forests and has resulted in extensive tree mortality in countries such as China, Japan, Republic of Korea and Portugal (Shi, 2005). It was apparently introduced to Japan on North American timber imports in the early 1900s and since then it has caused major epidemics of pine wilt disease (Krcmar-Nozic, Wilson and Arthur, 2000). The pest was intercepted in shipments of wood chips to Finland and Sweden. As a result, *B. xylophilus* is listed as an A1 quarantine pest by EPPO and regulations have been imposed on Canadian and United States shipments of unprocessed coniferous wood products since the early 1990s (EPPO/CABI, 1997). Such regulations have resulted in significant economic losses to Canada and the United States, as decreased exports of coniferous wood and wood products to Europe has cost both countries hundreds of millions of dollars (FAO, 2000; Allen and Humble, 2002).

INTRODUCED INSECTS

A number of destructive forest pests have been introduced into North America. Coleopteran species include the Asian longhorned beetle, emerald ash borer, banded elm bark beetle, pine shoot beetle and the brown spruce longhorn beetle. Discovered in 2002 in Michigan (United States) and Ontario (Canada), the emerald ash borer (*Agrilus planipennis**) is threatening ash trees (*Fraxinus* spp.) in North American forests, urban plantings and shelterbelts (Thomas, 2005). In June 2008 it was also reported from the province of Quebec, Canada (CFIA, 2008a). This native of Asia kills trees by feeding under the bark and disrupting the flow of nutrients and water throughout the tree (CFS, 2006a). It is responsible for the death and decline of millions of trees in the region and as a result it is considered a major pest problem; many believe the potential for damage to ash trees and overall biodiversity could rival the devastation caused by Dutch elm disease and chestnut blight. The emerald ash borer could also become a major threat to other countries.

The Asian longhorned beetle (*Anoplophora glabripennis**) was first discovered in the United States in Amityville, New York in 1996 followed by three separate infestations in Chicago, Illinois in 1998 and one in Jersey City, New Jersey in 2002. A very aggressive quarantine and eradication programme was implemented by the USDA Animal and Plant Health Inspection Service (APHIS) at all sites after detection. In September 2003, the beetle was discovered in Toronto, Ontario, Canada. The area was immediately quarantined by the Canadian Food Inspection Agency (CFIA) and an eradication programme was initiated involving the removal of infested trees, which has contained the spread of the beetle. This insect attacks many hardwood species in North America including maple, elm, birch, horse chestnut, willow and sycamore (CFIA, 2008b).

The pine shoot beetle (*Tomicus piniperda*), a European species, was discovered in North America in 1992. As of December 2002, twelve states in the United States (Illinois, Indiana, Maine, Maryland, Michigan, New Hampshire, New York, Ohio, Pennsylvania, Vermont, West Virginia and Wisconsin) and two Canadian provinces (Ontario and Quebec) were known to have infestations of *Tomicus piniperda* (Haack and Poland, 2001). Pines are the preferred hosts although the pest also attacks *Abies, Larix, Picea* and *Pseudotsuga* species.

Native to Europe, the brown spruce longhorn beetle (*Tetropium fuscum*) was found in dying red spruce (*Picea rubens*) trees in Halifax, Nova Scotia, Canada in 1999 (Hurley *et al*., 2004). White spruce (*Picea glauca*) and black spruce (*P. mariana*) have also been attacked. The beetle is believed to have entered the region on wood packing materials or dunnage (Hurley *et al*., 2004). Federal and provincial agencies are carrying out a survey and eradication programme.

Native to eastern Russian Federation, China, Democratic People's Republic of Korea, Kazakhstan, Kyrgyzstan, Mongolia, Republic of Korea, Tajikistan, Turkmenistan and Uzbekistan, the first specimens of the banded elm bark beetle (*Scolytus schevyrewi*) were trapped in Colorado and Utah, United States in 2003 although it is suspected that this insect had been present for several years (Thomas, 2005). This pest has been collected from *Ulmus americana, U. pumila, U. thomasii* and *U. procera* in the United States and is suspected to transmit Dutch elm disease (EPPO, 2008).

The gypsy moth, *Lymantria dispar**, is a significant pest of oaks, poplars, and maples, but is also capable of feeding on over 500 different plant and tree species. Two strains of gypsy moth have been recovered in North America: the Asian strain (not established), of which the female is capable of flight; and the European strain, of which the female is flightless (Brandt, 1994). The Asian strain was introduced into western North America on several occasions but in each case it was eradicated. While the pest has been prevented from establishing in the region, the costs associated with eradicating the Asian gypsy moth have been enormous, estimated at US$34 million for two introductions (Pacific Northwest, North and South Carolina) in the United States alone (Krcmar-Nozic, Wilson and Arthur, 2000). Coupled with the costs of border vigilance and monitoring, the economic losses are enormous. The European strain was introduced into the northeastern United States in 1869 and is now found primarily in eastern Canada and the United States. In Canada, this strain of gypsy moth was found first in Quebec in 1924 and then in New Brunswick in 1936; both of these infestations were eradicated (Brandt, 1994). In the last 20 years, however, Quebec, Ontario, New Brunswick and Nova Scotia have all been infested with the European strain (Brandt, 1994). The European gypsy moth is considered the most costly of introduced forest insect pests. In the United States, annual expenditures for control have exceeded US$35 million since 1980 (Wallner 1996, 1997). In addition, timber losses have been estimated at over US$291 million (Krcmar-Nozic, Wilson and Arthur, 2000).

A new pest in eastern Canada and the United States is the European woodwasp, *Sirex noctilio**. Native to Asia, northern Africa and Europe, this insect has been introduced into many countries in the southern hemisphere where it has caused significant damage to conifer trees, pines in particular. The woodwasp was discovered in the United States

(New York) in 2004 and in Canada (Ontario) in 2005 (Haugen and Hoebeke, 2005; CFS, 2006a). Since these initial introductions, the pest has spread throughout various counties in the Canadian province of Ontario and also to parts of the United States including Michigan, Pennsylvania and Vermont (P. de Groot, personal communication). Monterey (*Pinus radiata*), lodgepole (*P. contorta*), ponderosa (*P. ponderosa*), jack (*P. banksiana*), and most species of southern pines are known hosts; the susceptibility of other North American conifers is not known (Tkacz, Moody and Villa Castillo, 2007). Based on its behaviour in other countries, it is expected that, without adequate control measures, sirex will spread rapidly throughout the region. It is thus considered a serious pest in the region.

At least five species of adelgids have been introduced into North America (Blackman and Eastop, 1984). Two species have caused extensive tree mortality: the balsam woolly adelgid (*Adelges piceae*) and the hemlock woolly adelgid (*Adelges tsugae*). The balsam woolly adelgid is a major pest of true firs and the greatest cause of balsam fir (*Abies balsamea*) mortality in North America. It was accidentally introduced into Canada and the United States from Europe in the early part of the twentieth century (CFS, 2006b). Native to China and Japan, the hemlock woolly adelgid was first reported in western Canada (British Columbia) in the 1920s and in the United States (Virginia) in the 1950s (Thomas, 2005). This pest attacks spruce and hemlock trees. In the eastern United States, eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*T. caroliniana*) are susceptible to infestations; in western Canada, damage to western hemlock (*T. heterophylla*) has been minor.

INTRODUCED DISEASES

Many of the major diseases impacting North American forests are introduced species. Dutch elm disease (*Ophiostoma ulmi*) is the most destructive disease of wild and planted elm trees (*Ulmus* spp.) in North America (Ip, 1992). It was first found in Ohio in 1930 and has since spread throughout almost the entire North American range of elms. In Manitoba, the disease was found for the first time in 1975, and in 1981 it appeared in Saskatchewan. Over 35 million elms in the United States and millions of elms in eastern Canada have been killed by this disease resulting in significant landscape destruction (Ip, 1992).

White pine blister rust (*Cronartium ribicola*), an introduced fungus from Asia, has decimated several species of native white pines across the western United States and Canada (Thomas, 2005). It entered North America through the east and west coasts on European nursery stock around 1910.

Sudden oak death, *Phytophthora ramorum**, causes a serious disease of tanoak and oaks, resulting in crown dieback, stem bark lesions and basal cankers (Thomas, 2005). It attacks a variety of tree species including coast live oak (*Quercus agrifolia*), California black oak (*Q. kelloggii*), shreve oak (*Q. parvula* var. *shrevei*), tanoak (*Lithocarpus densiflorus*) and madrone (*Arbutus* spp.), and also infects several other plant species (Thomas, 2005). Infected trees die relatively quickly once crown symptoms develop although the severity of damage varies considerably between sites.

Beech bark disease, caused by the fungus *Nectria coccinea* var. *faginata*, causes significant damage or mortality in American beech (*Fagus grandifolia*). The disease results when bark that is attacked and altered by the beech scale (*Cryptococcus fagisuga*) is invaded and killed by fungi, primarily *Nectria coccinea* var. *faginata* and sometimes *N. galligena*. It was introduced to North America at Halifax, Nova Scotia in the 1890s and it killed entire stands of American beech as it spread north and west throughout the Canadian Maritime Provinces and in localized areas of eastern and south-central Maine (Houston and O'Brien, 1983).

Butternut canker (*Sirococcus clavigignenti-juglandacearum*) is a significant pest of *Juglans* species, primarily butternut, *J. cinerea.* The natural range of butternut extends throughout the northern and eastern United States and southern portion of eastern

Canada. The fungus was first reported in Wisconsin in 1967, but the causal agent was not isolated and described until 1979. It is not known how long it has existed in North American hardwood forests or if it was native or introduced, but there is evidence that it was introduced into the United States in the 1960s or earlier (EPPO, 2005). The pathogen spread rapidly across the United States and is now present in the entire native distribution area of *J. cinerea*. It was detected in Canada for the first time in Quebec in 1990 and in Ontario in 1991 (EPPO, 2005). The canker is currently known to exist throughout the range of butternut in Canada.

CAPACITY FOR FOREST HEALTH PROTECTION

The capacity for forest health protection in the region is high. Both Canada and the United States are very active in the area of forest health and protection. They have clear and comprehensive pest management programmes at both national and provincial/state levels, efficient monitoring and detection activities and sophisticated systems for data management. There is significant high quality information publicly available on specific pests with alerts for particularly noxious pests.

REGIONAL PEST MANAGEMENT EFFORTS

North America has several mechanisms for promoting regional cooperation on forest health issues. The working group for forest insects and disease of the North American Forest Commission (NAFC) was established over 40 years ago and was recently amended to include invasive plant species. In addition, the North American Plant Protection Organization (NAPPO), recognized under the IPPC, offers mechanisms for regional coordination on phytosanitary matters, including those for reporting on pests and activating alerts, as well as providing fact sheets.

Global analysis

PEST TYPE

Almost 77 percent of the forest pests reported from the overview countries were insect pest species (Table 11). All regions reported significantly more insect pests than other pest types (Figure 11; Table 12). Sixteen percent of the pest species were pathogens and the remaining 7 percent were other pests.

Insects tend to be easier to trap than other pests and easier to identify as the cause of tree damage, although identification still requires specialized training and expertise. The impacts of pathogenic diseases on forest trees, such as destruction of internal wood, reductions in growth, or delayed regeneration, are often subtle and difficult to detect. It can be difficult to determine the causative agent of these impacts. Likewise, the impacts of other pests such as nematodes, mites, mammals and parasitic plants on forest trees are not easy to detect.

INDIGENOUS VERSUS INTRODUCED PESTS

A large majority of the forest pests reported from the overview countries are indigenous species (Table 11). All regions reported more indigenous pest species than introduced species (Figure 11). Latin America and the Caribbean, however, reported almost equal numbers of indigenous and introduced species.

Eleven of the pest species were reported as both indigenous and introduced – the fungal pathogens *Armillaria mellea**, *Botryosphaeria dothidea**, *Nattrassia mangiferae* and *Subramanianospora vesiculosa* and the insect pests *Brontispa longissima*, *Coptotermes gestroi*, *Hylurgus ligniperda*, *Hypsipyla grandella**, *Hypsipyla robusta**, *Pineus pini* and *Xylosandrus morigerus*.

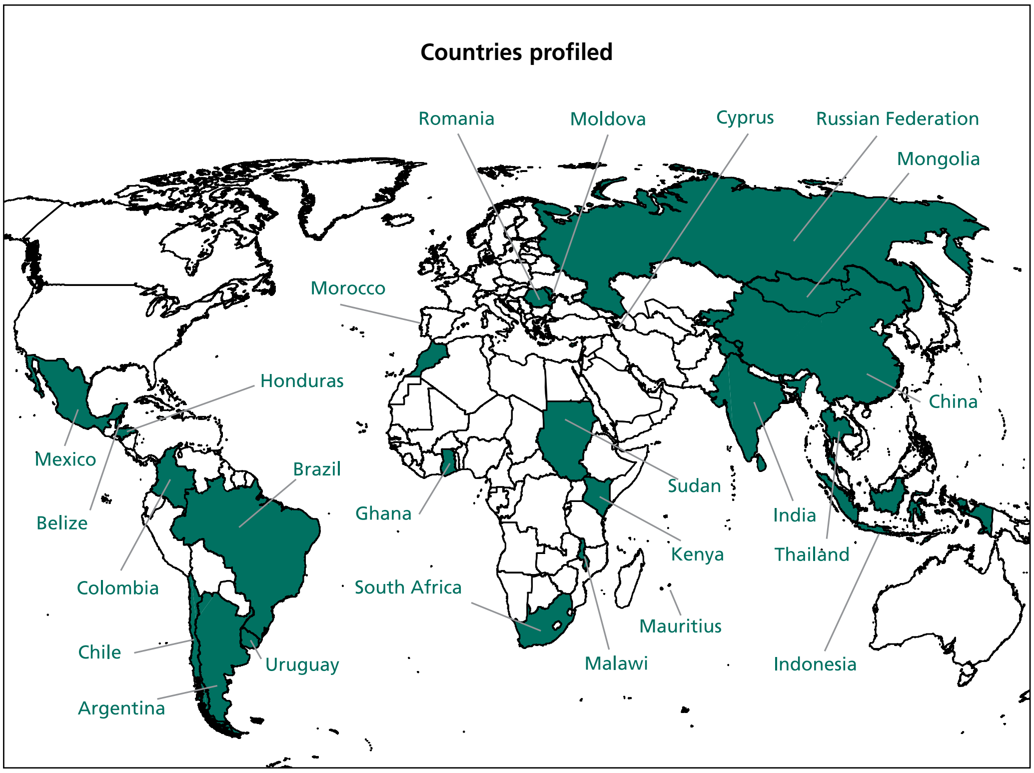


FIGURE 11
Number of pest species by region as reported from the selected 25 countries

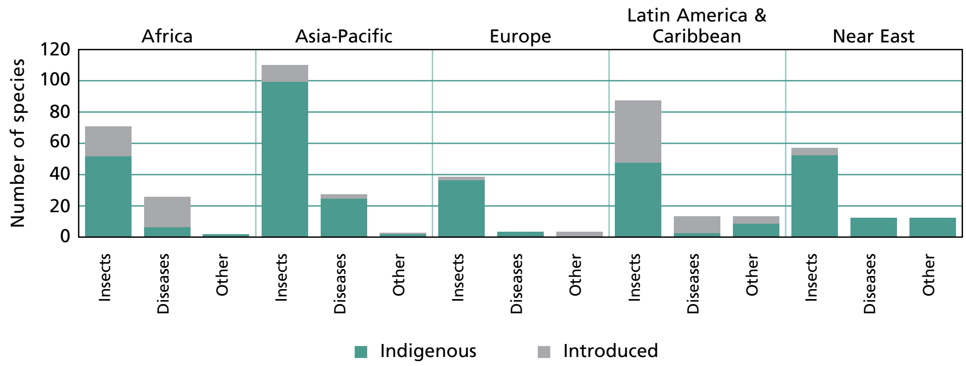


TABLE 11
Summary of the data on forest pest species from the 25 countries

Pest type	Number of pest species						
	Total	In naturally regenerated forests	In planted forests	In both types of forest	On broadleaf	On conifer	On both host types
Indigenous species							
Insects	277	102	135	39	178	80	18
Diseases	46	7	30	9	34	8	4
Other	22	14	7	1	14	5	3
Total	344	123	172	49	226	93	25
Introduced species							
Insects	64	3	49	12	28	34	2
Diseases	28	2	22	4	17	6	5
Other	9	7	1	1	5	1	3
Total	101	12	72	17	50	41	10
Total all regions [a]	**434**	**135**	**235**	**64**	**268**	**132**	**34**

[a] Eleven pest species (*Armillaria mellea**, *Botryosphaeria dothidea**, *Brontispa longissima*, *Coptotermes gestroi*, *Hylurgus ligniperda*, *Hypsipyla grandella**, *Hypsipyla robusta**, *Nattrassia mangiferae*, *Pineus pini*, *Subramanianospora vesiculosa and Xylosandrus morigerus*) were reported as both indigenous and introduced pests. These species were included in each section but were counted only once in the total.

TABLE 12
Prevalent characteristics of pest problems by region (from the 25 forest pest overviews)

Region	Pest type	Indigenous/ introduced	Planted/ naturally regenerated	Host type	Insect pest order	Disease order	Other pest order
Africa	Insect	Indigenous	Planted	Broadleaf	Coleoptera, Lepidoptera	Ascomycota	Primata
Asia and the Pacific	Insect	Indigenous	Planted	Broadleaf	Coleoptera, Lepidoptera	Ascomycota	Tylenchida, Rodentia
Europe	Insect	Indigenous	Naturally regenerated	Broadleaf	Lepidoptera	Ascomycota	Artiodactyla
Latin America and the Caribbean	Insect	Indigenous	Planted	Broadleaf	Coleoptera	Ascomycota	Santalales
Near East	Insect	Indigenous	Naturally regenerated	Broadleaf	Coleoptera	Basidiomycota	Acarina

Indigenous pests and signs of their infestation are often well-known to foresters and forest workers in the region. Previous experience with the pests leads to better and faster identification. Introduced pest species are usually more difficult to identify and detect owing to lack of knowledge of their biology and associated symptoms and lack of monitoring for such species.

TYPE OF FOREST

Over 54 percent of pests in the overview countries were recorded in planted forests, 31 percent in naturally regenerated forests and almost 15 percent in both forest types (Table 11). Planted forests are growing in importance but represent just 6.9 percent of the global forest total (271 million hectares) (FAO, 2006b). Nearly half of the world's planted forests are in Asia, almost 30 percent in Europe, 11 percent in North and Central America, 6 percent in Africa, 5 percent in South America and just over 1 percent in Oceania (FAO, 2006b). The pest data are likely to be skewed positively towards planted forests. Because of their commercial and economic importance, more attention is often paid to their health and monitoring, and pests in these forests are more often detected, identified, dealt with and reported.

Forest plantations of single tree species may have higher risk of major insect or disease infestation. In more diverse forest ecosystems, the risk of major infestations is not considered to be as high.

Three of the regions reported more species impacting planted forests than naturally regenerated forests: Asia and the Pacific (77 percent); Latin America and the Caribbean (65 percent); and Africa (59 percent) (Table 12). A number of countries with the largest planted forest area in Asia and the Pacific and in Latin America and the Caribbean were included in this analysis. Therefore, it is not surprising that more pests were reported from planted forests in these regions. A similar result was noted for Africa, where two countries with particularly large planted forest area, the Sudan and South Africa, were included in the overview.

Europe and the Near East, regions with the lowest sample sizes, reported more pest species in naturally regenerated forests, almost 62 percent and 51 percent respectively. Although planted forests are an important category in Europe, many of the countries that contribute to the large area, such as Sweden, Finland and France, were not part of the review. The Near East is represented by only two countries, Cyprus and Kyrgyzstan, and Kyrgyzstan provided more information on the naturally regenerated forests than on the remote and less accessible planted forests in the country.

Belize, Honduras, Kyrgyzstan, Malawi, Moldova and Romania reported more pests in naturally regenerated forests, while Mongolia, Russian Federation and Cyprus reported pests in equal numbers in both forest types.

Over 73 percent of pests in planted forests and 91 percent in naturally regenerated forests were indigenous species (Table 11). Introduced pests were found more prevalently in planted forests than naturally regenerated forests. This is notable since many planted forest trees are comprised of exotic species that were introduced for particular purposes. These may be more susceptible to introduced pests which, in the absence of natural enemies, can build up into large numbers (FAO, 2001). In addition, introduced pests are often difficult for foresters and forest workers to detect and identify due to lack of knowledge about the pest and its biology.

HOST TYPE

Almost 62 percent of forest pests were recorded on broadleaf tree species, over 30 percent on conifers and almost 8 percent on both host types (Table 11). In all regions, pests were recorded more often on broadleaf trees than conifers.

In 16 of the 25 overview countries, broadleaf tree species were the most commonly affected host species. Argentina, Belize, Cyprus, Honduras, Mexico, Mongolia, Morocco and the Russian Federation reported more pests on conifers. Kenya, reported equal numbers on both host types.

Broadleaf trees in planted forests were more affected by forest pests than those in naturally regenerated forests. The proportion of conifer pests in each forest type also exhibited the same pattern.

FIGURE 12
Insect pests reported from the 25 countries

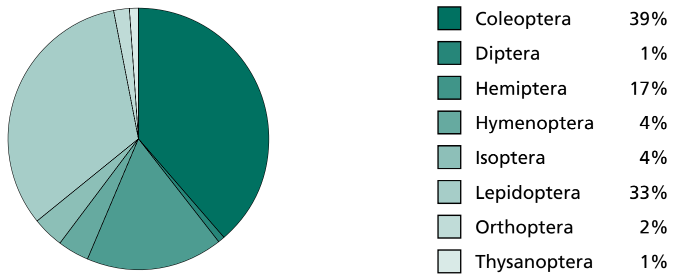


FIGURE 13
Disease-causing pathogens reported from the 25 countries

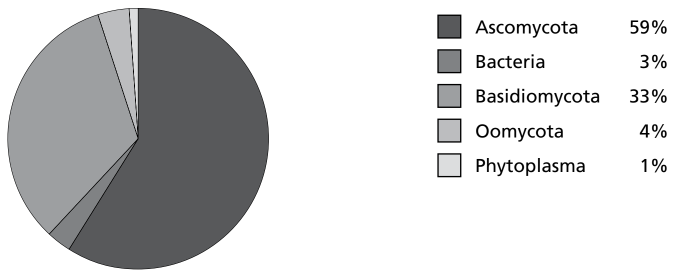
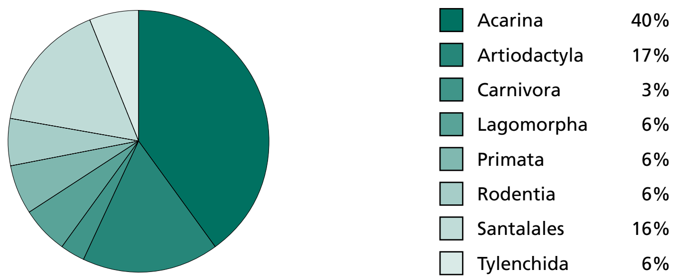


FIGURE 14
Other pests reported from the 25 countries



PREVALENT PEST SPECIES

For insect pests, the most commonly reported pest species belong to the orders Coleoptera and Lepidoptera which together made up over 70 percent of all insect pest species reported (Figure 12). Hemipteran species were the third most important insect order at 16 percent. In Africa and Asia and the Pacific, both Coleoptera and Lepidoptera made up the majority of pest species reported. Europe reported more lepidopterans and Latin America and the Caribbean reported more coleopterans.

For diseases, the majority of species were members of the phylum Ascomycota which represented almost 60 percent of all pathogens reported (Figure 13). Basidiomycota species were the next major group at 33 percent. Four of the regions reported more Ascomycota species while the Near East reported more Basidiomycota species.

For the category other pests (Figure 14), Acarina species were the most common followed by Artiodactyla species (even-toed ungulates) and Santalales (mistletoes and parasitic plants). Nematodes, rodents and primates were also classified as important pests. Africa reported more primate species, Europe more Artiodactyla, Latin America and the Caribbean more mistletoes and parasitic plants, and the Near East more Acarina species. In the Asia and Pacific region, nematodes and rodents were equally reported.

TRANSBOUNDARY PESTS

Twenty-five insect pest species were recorded in more than one region (Table 13). In order of importance are coleopterans (9), lepidopterans (7), hemipterans (6), hymenopterans (2) and isopterans (1). Bark beetles (Curculionidae, Scolytinae) were the most prevalent order.

Eleven of the above are introduced species, eight are indigenous and six are both indigenous and introduced depending on the country from which the species was reported. Twelve of the pests were recorded in planted forests, one in naturally regenerated forests and 12 in both forest types. Conifers were the host species for 12 of the transboundary pests, broadleaf trees for 12, and one pest was reported on both host types.

Nine disease-causing pathogens were reported from more than one region (Table 14). The majority of these were species of the phylum Ascomycota; the remainder were Basidiomycota species. Five of the pathogens are introduced species and four are both indigenous and introduced depending on the country from which they were reported. Seven of the pests were recorded in planted forests and two in both forest types. Broadleaf trees were the hosts for six of the transboundary pests, conifers for two species, and one pathogen was recorded on both host types.

In the category other pests, genera but not species were repeated for more than one continent, e.g. *Arceuthobium* was reported on conifers in Latin America and the Caribbean (*Arceuthobium* spp. in Mexico) and the Near East (*A. oxycedri*, Kyrgyzstan); and deer (*Cervus* spp.) were reported as pests of naturally regenerated forests in Latin America and the Caribbean (*Cervus elaphus*, Chile) and Europe (*Cervus nippon*, Moldova).

CAPACITY FOR FOREST HEALTH PROTECTION

Countries are increasingly recognizing the importance of environmental and biodiversity issues, including health and protection, to effective forest management. Many countries have national centres dedicated to forest research and in some countries there are also centres for forest health and protection. A number of constraints have been noted from the regions, including outdated equipment and lack of financial resources and specialized training.

TABLE 13
Insect pest species reported across regional borders from the 25 countries

Insect pest species	Order: family	Countries of occurrence	Indigenous/ introduced	Type of forest	Host type
*Cinara cupressivora**	Hemiptera: Aphididae	Africa: Kenya, Malawi, Mauritius Latin America and Caribbean: Chile, Colombia	Introduced	Naturally regenerated, planted	Conifer
*Cinara pinivora**	Hemiptera: Aphididae	Africa: Kenya Latin America and Caribbean: Argentina, Brazil	Introduced	Planted	Conifer
Coptotermes gestroi	Isoptera: Rhinotermitidae	Asia and Pacific: Thailand Latin America and Caribbean: Mexico	Indigenous, introduced	Planted	Broadleaf
*Dendrolimus sibiricus**	Lepidoptera: Lasiocampidae	Asia and Pacific: China, Mongolia Europe: Russian Federation	Indigenous	Naturally regenerated, planted	Conifer
Erannis defoliaria	Lepidoptera: Geometridae	Europe: Moldova, Romania Near East: Kyrgyzstan	Indigenous	Naturally regenerated	Broadleaf
Eulachnus rileyi	Hemiptera: Aphididae	Africa: Kenya, Malawi Latin America and Caribbean: Argentina, Chile, Colombia	Introduced	Naturally regenerated, planted	Conifer
*Gonipterus scutellatus**	Coleoptera: Curculionidae	Africa: Kenya, Mauritius, South Africa Latin America and Caribbean: Chile	Introduced	Planted	Broadleaf
*Heteropsylla cubana**	Hemiptera: Psyllidae	Africa: Kenya, Malawi, Mauritius, Sudan Asia and Pacific: India, Indonesia, Thailand	Introduced	Planted	Broadleaf
Hylurgus ligniperda	Coleoptera: Scolytidae	Africa: South Africa Latin America and Caribbean: Chile	Indigenous, introduced	Naturally regenerated, planted	Conifer
Hyphantria cunea	Lepidoptera: Arctiidae	Asia and Pacific: China Europe: Moldova, Romania Near East: Kyrgyzstan	Introduced	Naturally regenerated, planted	Broadleaf
*Hypsipyla grandella**	Lepidoptera: Pyralidae	Africa: Mauritius Latin America and Caribbean: Argentina, Belize, Brazil, Colombia, Mexico, Uruguay	Indigenous, introduced	Planted	Broadleaf
*Hypsipyla robusta**	Lepidoptera: Pyralidae	Africa: Ghana, Mauritius Asia and Pacific: India, Indonesia, Thailand	Indigenous, introduced	Planted	Broadleaf
*Ips sexdentatus**	Coleoptera: Scolytidae	Asia and Pacific: Mongolia, Thailand Europe: Romania, Russian Federation	Indigenous	Naturally regenerated, planted	Conifer

Insect pest species	Order: family	Countries of occurrence	Indigenous/ introduced	Type of forest	Host type
*Leptocybe invasa**	Hymenoptera: Eulophidae	Africa: Kenya, Morocco, South Africa Asia and Pacific: India	Introduced	Planted	Broadleaf
*Lymantria dispar**	Lepidoptera: Lymantriidae	Africa: Morocco (European strain) Asia and Pacific: China and Mongolia (Asian) Europe: Moldova and Romania (European), Russian Federation (Asian) Near East: Cyprus (European), Kyrgyzstan (Asian)	Indigenous	Naturally regenerated, planted	Broadleaf, Conifer
*Orthotomicus erosus**	Coleoptera: Scolytidae	Africa: Morocco Near East: Cyprus	Indigenous	Naturally regenerated, planted	Conifer
*Phoracantha recurva**	Coleoptera: Cerambycidae	Africa: Malawi, Morocco, South Africa Latin America and Caribbean: Chile, Uruguay	Introduced	Planted	Broadleaf
*Phoracantha semipunctata**	Coleoptera: Cerambycidae	Africa: Malawi, Morocco, South Africa Latin America and Caribbean: Chile	Introduced	Planted	Broadleaf
Pineus pini	Hemiptera: Adelgidae	Africa: Kenya, Malawi, South Africa Asia and Pacific: India Near East: Kyrgyzstan	Indigenous, introduced	Planted	Conifer
Quadraspidiotus perniciosus	Hemiptera: Coccidae	Asia and the Pacific: India Near East: Kyrgyzstan	Introduced	Naturally regenerated, planted	Broadleaf
*Sirex noctilio**	Hymenoptera: Siricidae	Africa: South Africa Latin America and Caribbean: Argentina, Brazil, Chile, Uruguay	Introduced	Planted	Conifer
*Thaumetopoea pityocampa**	Lepidoptera: Thaumetopoeidae	Africa: Morocco Near East: Cyprus (*Thaumetopoea wilkinsoni*)	Indigenous	Naturally regenerated, planted	Conifer
Tomicus minor	Coleoptera: Scolytidae	Asia and Pacific: Mongolia Europe: Romania Near East: Cyprus	Indigenous	Naturally regenerated, planted	Conifer
Tomicus piniperda	Coleoptera: Scolytidae	Asia and Pacific: Mongolia Europe: Romania, Russian Federation Near East: Cyprus	Indigenous	Naturally regenerated, planted	Conifer
Xylosandrus morigerus	Coleoptera: Scolytidae	Asia and Pacific: Indonesia Latin America and Caribbean: Mexico	Indigenous, introduced	Planted	Broadleaf

TABLE 14
Disease pest species reported across regional borders from the 25 countries

Disease species	Phylum: family	Countries of occurrence	Indigenous/ introduced	Type of forest	Host type
*Armillaria mellea**	Basidiomycota: Marasmiaceae	Africa: Kenya, Malawi, Sudan Near East: Kyrgyzstan	Indigenous, introduced	Naturally regenerated, planted	Broadleaf, Conifer
*Botryosphaeria dothidea**	Ascomycota: Botryosphaeriaceae	Africa: South Africa Asia and Pacific: Thailand Latin America and Caribbean: Uruguay	Indigenous, introduced	Planted	Broadleaf
*Chrysoporthe cubensis**	Ascomycota: Incertae sedis	Asia and Pacific: Thailand Latin America and Caribbean: Brazil, Colombia	Introduced	Planted	Broadleaf
Coniothyrium zuluense	Ascomycota: Leptosphaeriaceae	Asia and Pacific: Thailand Latin America and Caribbean: Uruguay	Introduced	Planted	Broadleaf
*Mycosphaerella pini**	Ascomycota: Mycosphaerellaceae	Africa: Kenya, South Africa Latin America and Caribbean: Chile	Introduced	Planted	Conifer
Nattrassia mangiferae	Ascomycota: Incertae sedis	Africa: Sudan Asia and Pacific: Thailand	Indigenous, introduced	Planted	Broadleaf
Phanerochaete salmonicolor	Basidiomycota: Phanerochaetaceae	Africa: South Africa Latin America and Caribbean: Brazil	Introduced	Naturally regenerated, planted	Broadleaf
Sphaeropsis sapinea	Ascomycota: Incertae sedis	Africa: Kenya, South Africa Latin America and Caribbean: Chile	Introduced	Planted	Conifer
Subramanianospora vesiculosa	Ascomycota: Incertae sedis	Africa: Mauritius Asia and Pacific: India, Thailand	Indigenous, introduced	Planted	Broadleaf

Monitoring and detection

In most of the regions, monitoring and detection activities are informal, involving field surveillance by foresters and forest workers, and many are targeted to specific pests. Some activities include aerial and ground surveys, mapping of winter nests and placement of pheromone traps. More activities are carried out in commercially valuable planted forests than in naturally regenerated forests.

Data management

In some areas advanced tools for data management are available, often developed as part of programmes to address specific forest pests. In most regions, however, data management capacity is lacking.

Most information on forest health is qualitative in nature. Very little quantitative data exist for many regions, and existing data are often not available in an easily accessible format. Data are often collected only after significant damage has been caused. Consistent data on the impacts of forest pests and diseases over time are not available for most regions.

Only 13 of the 25 overview countries provided quantitative data on forest health as part of the FRA 2005 process, and the information is still incomplete for many of these countries (Table 15). For these countries, the area affected by insects, diseases and other

TABLE 15

Total forest area and forest area affected by disturbances for the selected countries that provided quantitative information for the Global Forest Resources Assessment 2005

Country	Total forest area (*1 000 ha*)	Average forest area affected annually (*1 000 ha*)							
		Insects		Diseases		Other		Total	
		1990	2000	1990	2000	1990	2000	1990	2000
Brazil	477 698	50	30	–	20	–	–	50	50
Chile	16 121	866	531	13	810	–	–	879	1 341
China	197 290	7 879	6 191	1 820	883	755	820	10 454	7 894
Honduras	4 648	–	1	–	–	–	–	–	1
India	67 701	–	1	–	8	–	–	–	9
Indonesia	88 495	3	–	–	–	–	–	3	–
Kyrgyzstan	869	70	60	16	10	–	–	86	70
Mexico	64 238	8	8	11	2	–	–	19	10
Moldova	329	61[a]	96	–	–	–	–	61	96
Mongolia	10 252	28	2 798	–	–	–	–	28	2 798
Morocco	4 364	16	37	–	–	–	3	16	40
Russian Federation	808 790	1 718	4 953	124	957	–	–	1 842	5 910
South Africa[b]	9 203	2	1	–	–	–	–	2	1
Total	**1 749 998**	**10 701**	**14 707**	**1 984**	**2 690**	**755**	**823**	**13 440**	**18 220**

Source: FAO, 2006a

[a] The estimate for damage by insects for 1990 in Moldova may include some areas damaged by disease.

[b] Data for South Africa are from one source for planted forests only and refer to disturbances by weather, diseases, insects, animals and rodents.

pests and disturbances increased for the 2000 reporting period from the 1990 period by over 36 percent. For the 2000 reporting period, a total of over 18 million hectares were affected by forest pests; 14.7 million hectares damaged by insects, 2.7 million hectares by diseases and over 800 000 ha by other pests and disturbances. The total area affected was just over one percent of the total forest area of the countries reporting.

Pest management

Few comprehensive forest pest management plans exist for most regions and emphasis on preventative measures is for the most part lacking. A variety of pest management activities (biological, chemical, silvicultural) have been carried out in each region for specific pests. Such activities include the physical removal of infested trees and other silvicultural procedures, ground and aerial application of chemical and microbial pesticides, the use of biocontrol agents, and the planting of pest tolerant tree species.

Ownership

While forests are publicly owned in many of the regions, there is a trend from public to private ownership (FAO, 2007a). Little information is available on the capacity of private landowners in the area of forest health protection although it was noted that in many cases, they work collaboratively with national agencies, institutes and universities on such issues.

SUMMARY

Forest insect pests, diseases and other pests are having significant impacts on forests worldwide. While the devastating impacts of indigenous forest pests are already recognized, those of introduced species are increasingly being recognized as well. Rapid transport, ease of travel, and free trade have facilitated the spread of pests, as evidenced by the list of transboundary species (Tables 13 and 14).

There is a growing trend towards adopting more sustainable forest management strategies to contain forest pests, particularly in developed countries (FAO, 2007a). This movement is related to changes in the perception and role of forests, which are increasingly valued not just for economic reasons but also for their ecological and social functions.

Insect pests are the main problem reported. Disease-causing pathogens are more difficult to detect and identify and are reported less frequently. Training and expertise in pest identification and in detection of the first signs and symptoms are needed in many countries as a first line of defence against pest introductions.

Monitoring and surveillance of forest pests are needed, as well as agreement on parameters by which to gather data, in particular common definitions on what constitutes a disturbance and how the data are to be collected (FAO, 2007a).

Most countries do not have reliable information on the area of forest affected by insect pests and diseases because they do not systematically monitor these variables (FAO, 2007a). Data are often collected only after significant damage has been caused. More information is available on pests in commercially valuable planted forests than naturally regenerated forests. Awareness of the need to gather and share information on forest pests at national, regional and global levels is increasing.

Many strides have been made on forest health issues at regional and international levels by a variety of working groups, regional plant protection organizations, international organizations, research organizations and networks (Box 2). There have been concerted efforts to increase the free flow of information through networking and the Internet (Box 3) and to encourage compliance with international phytosanitary standards, especially those with direct relevance to forestry.

BOX 2

Regional and international groups and initiatives addressing forest health

- The International Union of Forest Research Organizations (IUFRO) has a number of divisions and units dedicated to research on a variety of forest health issues including entomology, pathology, invasive alien species and the impacts of air pollution and climate change on forest ecosystems.
- The International Plant Protection Convention (IPPC) targets the spread and introduction of pests of plants and plant products and promotes appropriate measures for their control (see Box 1).
- The working group for forest insects and disease of the North American Forest Commission (NAFC) was established over 40 years ago and was recently amended to include invasive plant species.
- Regional networks dealing with forest pests, primarily forest invasive species, include the Asia-Pacific Forest Invasive Species Network (APFISN), the Forest Invasive Species Network for Africa (FISNA), the Near East Network on Forest Health and Invasive Species (NENFHIS) and Red de Países de Cono Sur sobre Especias Exoticas Invasoras a Ambientes Forestales.
- In 1993, Near Eastern countries agreed to create the Near East Plant Protection Organization (NEPPO). This agreement has been ratified by eight countries (most recently the Syrian Arab Republic in July 2005), but two more ratifications are required for it to enter into force.
- A number of international instruments and organizations concentrate on the issue of invasive alien species such as the Global Invasive Species Programme (GISP), International Union for the Conservation of Nature (IUCN)/SSC Invasive Species Specialist Group (ISSG), Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention).

BOX 3

Sources of information on forest pests and invasive species

- FAO's forest health Web site: www.fao.org/forestry/pests
- FAO's invasive species Web site: www.fao.org/forestry/aliens
- FAO's forest biosecurity Web site: www.fao.org/forestry/biosecurity
- Forest Invasive Species Network for Africa (FISNA): www.fao.org/forestry/27679
- Asia-Pacific Forest Invasive Species Network (APFISN): www.fao.org/forestry/35067
- Center for Invasive Species and Ecosystem Health (Bugwood Network): www.forestpests.org
- Delivering Alien Invasive Species Inventories for Europe (DAISIE): www.europe-aliens.org
- Ecoport: www.ecoport.org
- European and Mediterranean Plant Protection Organization (EPPO) pest lists: www.eppo.org/QUARANTINE/quarantine.htm
- Exotic Forest Pest Information System for North America: spfnic.fs.fed.us/exfor
- Global Invasive Species Database (GISD), Invasive Species Specialist Group (ISSG), IUCN: www.issg.org/database
- Global Invasive Species Information Network (GISIN), list of invasive alien species (IAS) online information systems: www.gisinetwork.org/Documents/draftiasdbs.htm
- Near East Network on Forest Health and Invasive Species (NENFHIS): www.fao.org/forestry/51295
- Pacific Island Ecosystems at Risk (PIER): www.hear.org/pier/index.html
- Phytosanitary Alert System, North American Plant Protection Organization (NAPPO): www.pestalert.org
- Red de Países del Cono Sur sobre Especies Exoticas Invasoras a Ambientes Forestales: www.fao.org/forestry/52502
- Tree Protection Co-operative Programme (TCPC) pamphlets: www.fabinet.up.ac.za/tpcp/pamphlets

Conclusions

Given the vast benefits that forests and other wooded lands provide to the world, it is vital to protect these resources. This publication and many others on forest health illustrate that insect pests and diseases have had, and will continue to have, significant impacts on the world's forests and forest sector. In terms of sustainable forest management, minimizing the impacts of insects and diseases is no less important to a viable and strong forest sector than improving silvicultural and traditional forest management techniques.

Forest pests and diseases are a global problem and, consequently, it is necessary to look beyond national borders to develop effective solutions. The problem of intercontinental spread of insect pests and pathogens has raised serious concerns for some time now. In the past five years, the importance of invasive species and their impact on the environment has been increasingly recognized. More and more forest pest species appear to have been intentionally or accidentally introduced into areas beyond their natural ranges, resulting in a more extensive list of transboundary pests threatening forests and the forest sector worldwide. While this may seem to indicate that our ability to address the problem is progressively worsening, it is more likely that new introductions have increased as a result of the speed, volume and improved efficiency of the global trade market and that, fortunately, capacity to monitor and detect new pests and their impacts has improved.

Awareness of the need to gather and share information on forest pests at national, regional and global levels is increasing. Countries need to obtain reliable, quantitative information on the impacts of forest insect pests and diseases on a regular basis. At present, however, data are often collected only after significant damage has been caused and for most countries little information is available on pest impacts in naturally regenerated forests. Agreement is needed on the parameters by which to gather data and, in particular, on common definitions on what constitutes a disturbance and how the data are to be collected (FAO, 2007a).

Although many countries are adopting more pest management strategies to contain forest pests, greater recognition is still needed of the importance of pest management for effective forest management. Improving forest pest management involves increased research into the pests themselves and their control, increased taxonomic and diagnostic expertise to improve pest identifications, better monitoring and detection including the development of detection methodologies and diagnostic tools, research into new control technologies, and an overall increase in the capacity of all countries in forest health protection.

Over the past few decades, there has been a notable shift in requests to FAO: from requests for technical assistance for emergency control of pests to requests for help in increasing national or regional capacities in monitoring and prevention techniques for forest health and protection. Pest outbreaks are cyclical, occurring every 7 to 10 years, and the fact that there are fewer requests for emergency assistance for pests that were dealt with within the last decade suggests that countries have increased their capacity to deal with forest pest problems themselves. The progression of emphasis from dealing solely with pest emergencies towards more holistic approaches of prevention and improving national capacities needs to be continued.

The development and dissemination of effective control measures is vital to the protection of forest health. An evolution has been observed over the past few decades in terms of techniques and attitudes towards pest control. In the early 1960s a variety of methods were used to control forest insect pests and diseases including mechanical, silvicultural, chemical and biological methods, with chemical control the most commonly used. By the 1970s environmental concerns were being increasingly raised about the use of chemicals. As a result, research into the use of biological control agents in conjunction with silvicultural methods or pheromones began in earnest.

There is also a growing recognition of the importance of environmental policies and pesticide legislation. The Forest Stewardship Council (FSC), a non-governmental organization established to promote the responsible management of the world's forests, prohibits the use of highly hazardous pesticides and promotes the development and adoption of environmentally friendly non-chemical methods around the world. The FSC maintains a list of prohibited highly hazardous pesticides which includes chlorinated hydrocarbon pesticides, pesticides banned by international agreement, and pesticides that are persistent, toxic or whose derivatives remain biologically active and accumulate in the food chain beyond their intended use (FSC, 1996). Today, integrated pest management involving a combination of control measures is considered the most effective way to deal with forest pests. Applications of biological control agents and microbial insecticides have become major components of pest management programmes and considerable emphasis is placed on prevention and early detection as a means to avoid future pest problems.

Breeding trees for pest resistance is another technique that has grown in importance over the past few decades. Currently, there are many programmes on breeding for resistance of forest trees, and resistant hosts have been developed against a variety of forests pests. For example, strains of black poplar (*Populus nigra*) resistant to attack by the Asian longhorned beetle (*Anoplophora glabripennis**) have been developed in China (Hu *et al*., 2001), monterey pine (*Pinus radiata*) resistant to *Mycosphaerella pini** have been developed in New Zealand (Carson, 1990) and western white pine (*Pinus monticola*) have been bred for resistance to white pine blister rust (*Cronartium ribicola*) in Canada and the United States (Sniezko, 2006).

Cooperation and coordination of pest management activities between countries and regions is imperative, as are international activities, particularly those geared to developing international standards on pests and global trade. There is a need for increased pest reporting to National Plant Protection Organizations (NPPOs) and stronger links between the forest sector and the International Plant Protection Convention (IPPC). This has been improving: the IPPC has given greater recognition to forest pests and has adopted International Standards for Phytosanitary Measures (ISPMs) directly relevant to the forest sector. Recent focus is on better implementation of these complex international standards by translating them into more understandable and relevant terms for the use of all forest personnel dealing with phytosanitary issues.

The forest sector needs to be able to adapt to new situations and scenarios and this requires research, policies and practices that will enable it to plan and manage healthy forests to meet future needs. The impacts of a changing climate on forests and the possibility of increased susceptibility to forest insects and pathogens are of global significance in forest health today. Climate change is influencing not only trees and forests but also the way in which forestry is practiced. For example, climate change can stress forest ecosystems and may be a key factor in forest health decline. This has serious implications for forests in terms of altering pest distributions, population dynamics and behaviours. In response to such global concern, FAO, IUFRO, the Swedish University of Agricultural Sciences (SLU), USDA Forest Service, Seoul National University, and the Royal Swedish Academy of Agriculture and Forestry sponsored an international conference on Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health, held in Sweden in August 2008.

PART II

Profiles of selected forest pests

INSECT PESTS

Agrilus planipennis

Other scientific names: *Agrilus feretrius* Obenberger; *Agrilus marcopoli* Obenberger; *Agrilus marcopoli ulmi* Kurosawa
Order and Family: Coleoptera: Buprestidae
Common names: emerald ash borer; EAB

Agrilus planipennis Fairmaire, commonly known as the emerald ash borer, is a metallic wood-boring beetle that is a highly destructive pest of ash trees (*Fraxinus* spp.). This pest is native to eastern Asia and has been accidentally introduced into North America, presumably through infested wood-packaging materials from Asia, where it is a major threat to ash trees in forests, urban plantings and shelterbelts. It is responsible for the death and decline of millions of trees in Canada and the United States.

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Adult emerald ash borers, Agrilus planipennis

DISTRIBUTION

Native: Asia and the Pacific: Democratic People's Republic of Korea, Japan, Mongolia, People's Republic of China, Republic of Korea
Europe: Russian Federation
Introduced: North America: Canada (2002), United States (2002)

IDENTIFICATION

Adult beetles are metallic blue-green, slender, elongate, hairless and approximately 7.5 to 14 mm long and 3.1 to 3.4 mm wide (Kimoto and Duthie-Holt, 2006; McCullough and Katovich, 2004). The head is flat with a shield-shaped top and the kidney-shaped eyes are bronze or black. The prothorax, the segment behind the head which contains the first pair of legs, is slightly wider than the head and transversely rectangular, but is the same width as the base of the wing covers (Kimoto and Duthie-Holt, 2006; McCullough and Katovich, 2004). Males are smaller than females and are further distinguished by the presence of fine hairs on the ventral side of the thorax (McCullough and Katovich, 2004).

Mature larvae are white to cream-coloured, 26 to 32 mm long with broad flattened bodies (Kimoto and Duthie-Holt, 2006; McCullough and Katovich, 2004). The head is relatively small, brown and retracted inside the enlarged prothorax (Haack *et al*., 2002). The abdomen is 10-segmented, some with bell-shaped posterior ends. The first eight segments have one pair of spiracles each and the last segment has one pair of brownish, pincer-like appendages.

HOSTS

In its native distribution, hosts include *Fraxinus* species (*F. chinensis*, *F. japonica*, *F. lanuginosa*, *F. mandshurica*, *F. mandshurica* var. *japonica*, *F. rhynchophylla*); *Juglans* spp. (*J. mandshurica*, *J. mandshurica* var. *sieboldiana*); *Pterocarya* spp. (*P. rhoifolia*); and *Ulmus* spp. (*U. davidiana*, *U. davidiana* var. *japonica*, *U. propinqua*) (McCullough and Katovich, 2004; EPPO, 2005). In its introduced range in North America, only *Fraxinus* species (*F. americana*, *F. nigra*, *F. pennsylvanica*) have been attacked (Kimoto and Duthie-Holt, 2006).

BIOLOGY

The emerald ash borer typically has a one-year life cycle although in colder regions it could require up to two years to complete a generation (McCullough and Katovich, 2004). The length of the life cycle is also influenced by the age of the infestation, the health of host tree, and other biotic and abiotic factors (Bauer *et al*., 2007). Immature beetles maturation feed on the leaves of host trees, creating irregular notches in the leaves (Kimoto and Duthie-Holt, 2006). Females can mate multiple times and egg-laying begins a few days after the initial mating. Egg-laying peaks toward the end of June, but eggs are laid throughout the summer and into the fall due to a prolonged adult emergence period and long adult longevity (Bauer *et al*., 2007). Females can lay 60 to 90 eggs in their lifetime and they deposit them singly in bark crevices on the main trunk or branches (greater than 2.5 cm diameter) in the crown (Kimoto and Duthie-Holt, 2006; McCullough and Katovich, 2004).

Eggs hatch within 7 to 10 days after which first instar larvae bore through the bark until they reach the phloem where they continue feeding through four larval stages (Bauer *et al*., 2007). Flat and wide 'S-shaped' galleries are created that are filled with a fine brownish frass. Galleries are typically 9 to 16 cm long, but can reach lengths of 20 to 30 cm, and increase in width as the larva grows (Kimoto and Duthie-Holt, 2006; McCullough and Katovich, 2004).

Agrilus planipennis *larval galleries and adult exit holes*

Pupation occurs during the spring or summer and takes place at the end of a gallery either just beneath the bark near the surface of the sapwood (5 to 10 mm) or in the corky tissue of thick-barked trees (Kimoto and Duthie-Holt, 2006). Adult beetles emerge through small, distinct 'D-shaped' exit holes which are 3 to 4 mm in diameter. Emergence typically begins in late May and peaks in June (Bauer et al., 2007).

SYMPTOMS AND DAMAGE

In China, *A. planipennis* typically attacks ash trees in open areas or along forest edges while in North America it has infested ash trees in both open settings and closed forests (Haack *et al*., 2002). Attacks are initiated along the upper trunk and lower portions of the main branches with the lower trunk being the target in successive attacks (Haack *et al*., 2002). The borers are known to attack and kill trees of various sizes and conditions from small to large mature trees.

Trees attacked by the emerald ash borer are ultimately killed, typically within three years of the initial attack although under heavy infestations, trees can be killed within 1 to 2 years (Haack *et al*., 2002). This pest kills trees by feeding under the bark and disrupting the flow of nutrients and water throughout the tree (CFS, 2006a).

Symptoms of attack include frass-filled larval galleries in the cambium, adult exit holes, yellowing and thinning of foliage, dying of branches, dieback and mortality of the host tree. In response to larval feeding, callus tissue may be produced by the tree and may cause vertical bark cracks to occur over a gallery (Kimoto and Duthie-Holt, 2006). Woodpecker activity may also indicate the presence of this pest.

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Tree infested by Agrilus planipennis *exhibiting root sprouts and crown dieback*

DISPERSAL AND INTRODUCTION PATHWAYS

Adult emerald ash borers are strong fliers, typically in 8 to 12 m bursts, and have been known to fly over 1 km in search of suitable host material (Haack *et al*., 2002). Their relatively small size also subjects them to dispersal by air currents. Long distance spread, however, is primarily human assisted through the international trade and transport of plants, wood and wood products containing bark.

CONTROL MEASURES

No effective control methods are currently available although research is ongoing to investigate the biology of the pest, develop methods for early detection and evaluate possible control measures such as insecticides and natural enemies. Three hymenopteran parasitoids have been discovered in China that are considered suitable for use as biocontrol agents in North America including a larval ectoparasitoid *Spathius agrili*, a larval endoparasitoid *Tetrastichus planipennisi*, and a solitary, parthenogenic egg parasitoid *Oobius agrili* (Bauer *et al*., 2007). After consultations with scientists and land managers at federal and state agencies, university faculty members and the public, it was agreed that these parasitoids would be released at selected sites in Michigan, United States. Field releases of *O. agrili* and *T. planipennisi* began in July 2007 and releases of *S. agrili* were expected to begin in late summer or early fall (Bauer *et al*., 2007).

A. planipennis is classed as a quarantine pest in Canada and the United States and appears on the NAPPO alert list. Domestic phytosanitary measures have been imposed to restrict the movement of wood and wood products from infested to non-infested areas (Haack *et al*., 2002; CFS, 2006a). Regulated materials include: nursery stock; trees; logs; wood; rough lumber including pallets and other wood packaging materials; bark; wood chips or bark chips from ash (*Fraxinus* species); and firewood of all host tree species (CFIA, 2007). Canada and the United States are working together on strategies to combat the spread of this pest.

In 2002 the emerald ash borer was added to the EPPO A2 action list, and it has been recommended that EPPO member countries regulate it as a quarantine pest. Suggested phytosanitary measures for commodities of *Fraxinus* include origin from a pest-free area or heat treatment for wood and bark.

Anoplophora glabripennis

Other scientific names: *Anoplophora nobilis*; *Cerosterna glabripennis*; *Cerosterna laevigator*; *Melanauster nobilis*; *Melanauster luteonotatus*; *Melanauster angustatus*; *Melanauster nanakineus*
Order and Family: Coleoptera: Cerambycidae
Common names: Asian longhorned beetle; ALB; starry sky beetle; Basicosta white-spotted longicorn beetle

Anoplophora glabripennis Motschulsky, 1853 is a wood-boring beetle that is a major threat to broadleaved trees in both urban environments and naturally regenerated and planted forests. Native to China and Korea, it has been introduced into Europe and North America through international trade on wood packaging materials. As a result, many countries in other continents are increasingly concerned about this pest and have established phytosanitary restrictions for wooden packing materials from infested countries.


G. ALLARD


G. ALLARD

Asian longhorned beetles, China

DISTRIBUTION

Native: Asia and the Pacific: Democratic People's Republic of Korea, Japan, People's Democratic Republic of China, Republic of Korea (several records but no recent collections are known).
Introduced: North America: Introduced and under eradication in Canada (2003) and the United States (first introduced in 1990s, discovered in 1996).
Europe: Introduced but not established in Germany (Bayern), France (Gien, Sainte Anne sur Brivet, 2003), and Austria (Braunau, 2001), Poland (single specimen in 2003).

IDENTIFICATION

Typical adult Asian longhorned beetles are large (20 to 35 mm in length, 7 to 12 mm wide), shiny, and bluish-black in colour with white spots (Kimoto and Duthie-Holt, 2006). There is one prominent spine on each side of the black thorax. The antennae are black, spotted and very long; 2.5 times the body length in males and 1.3 times the body length in females (EPPO, 1999). The antennae have 11 segments, each with a white or whitish-blue base (Kimoto and Duthie-Holt, 2006). Legs are black with a bluish tinge. The *A. nobilis* form has yellow spots and is believed by some authorities to be a different species and by others as a different morphotype of a single species (Lingafelter and Hoebeke, 2002).

Larvae are legless creamy white grubs with a chitinized brown mark on the prothorax and when mature are up to 50 mm in length (EPPO, 1999; Kimoto and Duthie-Holt, 2006). The larvae and pupae are normally found inside the tree within the larval tunnels.

Eggs are off-white, oblong, approximately 5 to 7 mm in length with slightly concave ends (EPPO, 1999). They turn a yellowish-brown colour just before hatching.

HOSTS

In China, the major hosts are species and hybrids of the genus *Populus* including *P. nigra*, *P. deltoides*, *P.* x *canadensis* and the Chinese hybrid *P. dakhuanensis* (EPPO, 1999). *Salix* species, such as *S. babylonica* and *S. matsudana*, are also major hosts. Other hosts recorded in China include *Acer*, *Alnus*, *Malus*, *Melia*, *Morus*, *Platanus*, *Prunus*, *Pyrus*, *Robinia*, *Rosa*, *Sophora* and *Ulmus* species.

In North America, species of *Acer*, *Aesculus*, *Albizia*, *Betula*, *Celtis*, *Platanus*, *Populus*, *Salix*, *Sorbus* and *Ulmus* are known hosts (Kimoto and Duthie-Holt, 2006). The suitability of *Alnus*, *Crataegus*, *Elaeagnus*, *Fraxinus*, *Hibiscus*, *Malus*, *Morus*, *Prunus*, *Pyrus*, *Quercus*, *Robinia* and *Tilia* species in North America is still in question.

BIOLOGY

The life cycle of A. glabripennis is long but uneven, fecundity is high and there may be one or two generations per year (Pan, 2005). Adults may mate several times. Females chew oval oviposition slots (about 10 mm wide) and lay a single egg in the inner bark of the trunk, branches as small as 2 to 3 cm in diameter or exposed roots; exit holes left by emerging adults may also be used (Kimoto and Duthie-Holt, 2006; Pan, 2005). Frothy, white sap may exude from recently created oviposition niches which ferments and stains the bark over time.

Eggs hatch after approximately two weeks and larvae bore large galleries deep into the wood. Immature larvae feed on the inner bark and sapwood while mature larvae feed on the heartwood. Several larval tunnels may occur in the trunk which degrades the quality of timber and can even cause death of host trees (Pan, 2005). This beetle is able to survive and finish development in cut logs although females do not oviposit on dead, debarked wood. Adults emerge from host trees by chewing round exit holes, approximately 6 to 12 mm in diameter, and expelling large, coarse wood fibres on the ground (Kimoto and Duthie-Holt, 2006).


G. ALLARD

G. ALLARD

G. ALLARD

Damage caused by the Asian longhorned beetle, China

SYMPTOMS AND DAMAGE

Asian longhorned beetles are wood-borers that attack healthy and stressed trees. Adults feed on the leaves, petioles and twigs of host trees; feeding damage on young shoots causes them to wither and die (Kimoto and Duthie-Holt, 2006). Larval tunnels disrupt the vascular functioning of the host tree eventually weakening it to the point of death. Several generations can develop in one tree, causing severe damage.

Leaf yellowing and wilting, premature leaf drop, branch dieback and tree death are symptoms of advanced infestations of *A. glabripennis*. Infestations decrease diameter at breast height (DBH), tree height, timber volume, and biomass; these losses increase with forest age and pest density (Weilun and Wen, 2005).

According to experiments carried out in China, 4- to 10-year-old poplars die after 2 to 4 years of consecutive damage, and poplar forests grown in monoculture can die after 3 to 5 years of consecutive damage (Pan, 2005). Within 5 to 8 years, severe damage may occur depending on the host tree species, forest structure and growing status.

DISPERSAL AND INTRODUCTION PATHWAYS

The Asian longhorned beetle has a low dispersal rate. While adults are capable of flying 1 000 to 1 200 m per flight, short-distance flight is typical and they usually fly only 50 to 75 m in search of suitable hosts. Infestations spread slowly, reported as less than 300 m per year in Beijing poplar groves (Cavey, 2000).

The presence of preadult stages is usually not easily detectable hence eggs, larvae or pupae are readily dispersed in infested timber such as solid timber packaging and dunnage.

CONTROL MEASURES

Effective monitoring, quarantine and control of *A. glabripennis* are difficult since the adult stage can be short and detecting the early stages of damage during the concealed larval stages nearly impossible (Pan, 2005). Once *A. glabripennis* has infested a tree, the only treatment is to cut down, chip and burn the infested tree. In North America, eradication measures have been, and continue to be, carried out involving the removal of infested trees which has been successful in containing the spread of the beetle. Research aimed at providing technology to better detect, control and ultimately eradicate the pest from the region is ongoing.

In China, a variety of techniques have been investigated to control the pest including afforestation models, altering shelterbelt structure and composition, bait tree arrangement and treatment technology, application of synthetic pheromones, development of genetically modified poplars with resistance to pests, establishment of an eco-control system, and biocontrol applications such as the use of the parasitoid *Dastarcus helophorides* and woodpeckers (Weilun and Wen, 2005).

The establishment of the Asian longhorned beetle outside its native distribution has caused great concerns in many countries and is one of the invasive alien species that has led to the development of an international standard (ISPM No. 15) for the movement of wood packaging material that is treated to avoid phytosanitary risk.

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Control measures for the Asian longhorned beetle: insecticide impregnated sticks placed into the holes created by newly emerged larvae, China

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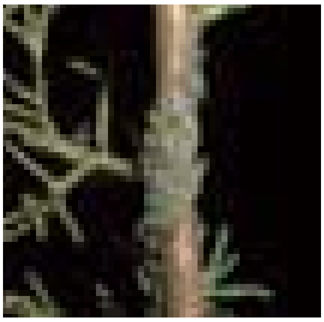
Removal and chipping of infested trees, Chicago, United States

Cinara cupressivora

Order and Family: Hemiptera: Aphididae
Common names: giant cypress aphid; cypress aphid

Cinara cupressivora Watson & Voegtlin, 1999 is a significant pest of Cupressaceae species and has caused serious damage to naturally regenerated and planted forests in Africa, Europe, Latin America and the Caribbean and the Near East. It is believed to have originated on *Cupressus sempervirens* from eastern Greece to just south of the Caspian Sea (Watson *et al*., 1999). This pest has been recognized as a separate species for only a short time (Watson *et al*., 1999) and much of the information on its biology and ecology has been reported under the name *Cinara cupressi*.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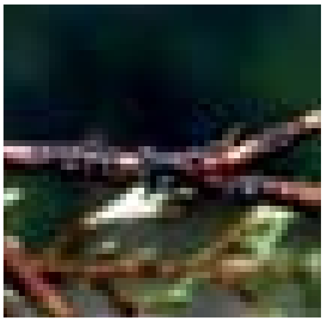
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Cypress aphids

DISTRIBUTION

Native: Europe and the Near East: eastern Greece to Islamic Republic of Iran
Introduced: Africa: Burundi (1988), Democratic Republic of Congo, Ethiopia (2004), Kenya (1990), Malawi (1986), Mauritius (1999), Morocco, Rwanda (1989), South Africa (1993), Uganda (1989), United Republic of Tanzania (1988), Zambia (1985), Zimbabwe (1989)
Europe: France, Italy, Spain, United Kingdom
Latin America and Caribbean: Chile (2003), Colombia
Near East: Jordan, the Syrian Arab Republic, Turkey, Yemen

IDENTIFICATION

Giant conifer aphid adults are typically 2 to 5 mm in length, dark brown in colour with long legs (Ciesla, 2003a). Their bodies are sometimes covered with a powdery wax. They typically occur in colonies of 20 to 80 adults and nymphs on the branches of host trees (Ciesla, 1991). Winged and non-winged adults can be found in the same colony.

Detailed descriptions of female adults are provided by Watson *et al*. (1999).

HOSTS

Austrocedrus chilensis; Callitris spp.; *Chamaecyparis* spp.; *Cupressus* spp., including *C. lusitanica*; *Juniperus* spp., including *J. bermudiana*; *Thuja* spp.; *Cupressocyparis* spp.; *Widdringtonia* spp., including *W. nodiflora*

Cinara cupressivora has a broad host range and would probably find any Cupressaceae species to be suitable host material (Ciesla, 2003a).

BIOLOGY

Cinara cupressivora has a high reproductive potential. Only females are present during the summer months which reproduce parthenogenetically and give birth to live young (Ciesla, 2003a). As cool weather approaches, both males and females are found and eggs are produced instead of live nymphs. Eggs are deposited in rough areas on twigs and foliage where they overwinter. Several generations are produced in a year and the life span of a single generation is about 25 days during the peak of the summer season (Ciesla, 2003a).

Damage caused by the cypress aphid, Kenya

SYMPTOMS AND DAMAGE

Adults and nymphs suck the plant sap on terminal growth of young and old trees (Ciesla, 1991). Feeding retards new growth and causes desiccation of the stems and a progressive dieback on heavily infested trees. Damage to host trees includes browning and defoliation which, in some cases, causes dieback and death of trees. A secondary problem caused by aphid feeding is the copious quantities of honeydew which encourages the growth of sooty mould (Ciesla, 1991). The mould causes foliage discolouration and interferes with photosynthesis and gas exchange.

The occurrence of adult and larval coccinellids is often an indicator of aphid infestation as is the presence of ants, which tend the aphids and feed on the honeydew.

DISPERSAL AND INTRODUCTION PATHWAYS

Winged adults are capable of flying short distances although this is not considered an important means of spread. Adults and nymphs can be spread from tree to tree by air currents. Ants have developed a symbiotic relationship with *Cinara* aphids and are known to move aphids to new hosts to maintain colonies capable of producing copious amounts of honeydew on which the ants feed (Ciesla, 2003a).

This insect's present widespread worldwide distribution suggests that it is easily transported on live plant materials. Extensive planting of conifers that are hosts for *Cinara* species and international transport of nursery stock are the primary human assisted means of spread of conifer aphids.

CONTROL MEASURES

Cultural and biological control tactics are available for management of damaging populations of *Cinara cupressivora*. Short-term protection of cypress hedges and small ornamental trees has been achieved with ground applications of chemical pesticides but this is not recommended. In Africa, observations indicate that cypress plantations established on good soils are more tolerant of aphid infestations than those established on shallow, rocky soils and young, fast-growing plantations are less susceptible to damage than mature plantations (Ciesla, 2003a). Based on these observations, proper site selection and timely harvesting of plantations should reduce losses.

Release of Pauesia *parasitoids for biocontrol of cypress aphid, western Kenya*

Biological control agents have been used successfully against several species of *Cinara*. The introduction of *Pauesia* spp. in Kenya and Malawi has significantly reduced the impact and spread of *C. cupressivora* (Day *et al.*, 2003). Larvae and adults of ladybird beetles and larvae of several species of syrphid flies (Diptera: Syrphidae) are natural control agents of the cypress aphid but they are not considered capable of controlling high populations (Ciesla, 2003a).

Cinara pinivora

Order and Family: Hemiptera: Aphididae
Common names: giant conifer aphid

Cinara pinivora Wilson, 1919 is sap-sucking aphid native to North America that has been introduced into Africa, Asia and the Pacific and Latin America and the Caribbean. A major pest of *Pinus* species, this aphid poses a significant threat to planted pine forests worldwide.

Cinara pinivora

DISTRIBUTION

Native: North America
Introduced: Africa: Kenya, Malawi
Asia and the Pacific: Australia
Latin America and the Caribbean: Argentina, Brazil (1996), Uruguay

IDENTIFICATION

The adult body length is typically 3.3 to 4.2 mm. The wingless form (apterae) have a shiny dark brown head, lighter brown thorax and abdomen with dark dorsal sclerites and spots of grey wax, and black steep-sided siphuncular cones. Legs have pale yellow sections. They are found in dense colonies at tips of branches, or scattered along older sections of twigs (Blackman and Eastop, 1994).

HOSTS

Pinus spp., including *P. elliottii* and *P. taeda*

BIOLOGY

A sap-sucking aphid, *Cinara pinivora* has a very short life cycle and is capable of multiplying rapidly. Some forms reproduce asexually at times and can therefore quickly build up numbers. Populations are extremely reduced during periods of high temperatures (Lázzari, Trentini and de Carvalho, 2004).

SYMPTOMS AND DAMAGE

Cinara pinivora forms dense colonies on all parts of host trees. It attacks young plantations of *Pinus* spp. infesting month old plants through to 3- to 4-year-old saplings and the tips of older plants. Damage starts as discolouration and premature needle fall with some branches turning brown. Inflammation of branches and mortality of plants has been observed in Brazil (Patti and Fox, 1981). The reduced photosynthetic surfaces results in stunting, affecting the form of host trees and reducing increments. A secondary problem caused by aphid feeding is the production of copious quantities of honeydew which encourages sooty mould growth.

DISPERSAL AND INTRODUCTION PATHWAYS

Winged adults are weak fliers, but are readily carried by wind over considerable distances. As adults or juveniles, they do not survive off host plant material for very long. Therefore, international transport of nursery stock is a significant pathway for the introduction of *C. pinivora*.

CONTROL MEASURES

According to Penteado (1995), biological control has been achieved in Brazil through the release of insect predators of the families Coccinellidae, Syrphidae, Chrysophidae, Staphilidae, Dermaptera and some Heteroptera.

Dendroctonus frontalis

Other scientific names: *Dendroctonus arizonicus* Hopkins
Order and Family: Coleoptera: Scolytidae
Common names: southern pine beetle; bark beetle; el gorgojo (Central America); tree killer

Dendroctonus frontalis Zimmerman, 1868 is considered to be one of the most damaging species of bark beetles in Central America and southern areas of North America. It is a major pest of pines and has a wide distribution occurring from Pennsylvania in the United States south to Mexico and Central America.


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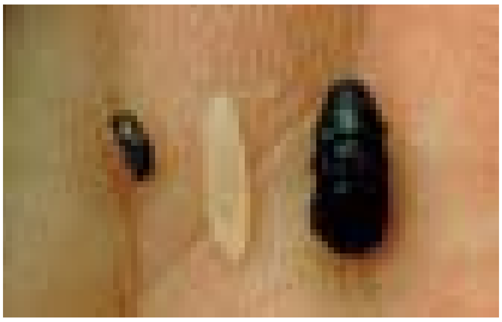
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Southern pine beetle, Dendroctonus frontalis. *On the right, an adult is compared to a grain of rice and an adult black turpentine beetle (l-r)*

DISTRIBUTION

Native: Latin America and the Caribbean: Central America (Belize, El Salvador, Guatemala, Honduras, Nicaragua), Mexico
North America: southern United States
Introduced: Europe: Ireland (intercepted only)
Near East: Israel (intercepted only)

IDENTIFICATION

Adult southern pine beetles are short-legged, stout, about 3 mm long and dark reddish brown to black in colour (Thatcher and Barry, 1982; USDA Forest Service, 1989). The front of its head is notched and the hind end of the body is rounded. Newly emerged adults are soft-bodied and amber coloured but quickly harden and darken in colour (Thatcher and Barry, 1982). Larvae are crescent-shaped, whitish with an amber head and approximately the same length as adults when fully developed (USDA Forest Service, 1989). The pupae are also the same size and white. Eggs are smooth, pearly-white and found in notches along either side of the adult egg galleries.

HOSTS

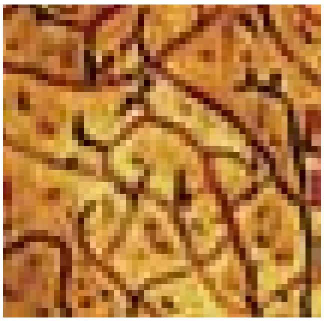
Pinus spp., primarily *P. taeda*, *P. echinata*, *P. elliottii*, *P. virginiana*, *P. rigida*, *P. palustris*, *P. serotina, P. pungens* and the introduced *P. strobes* in southeastern United States; *P. ponderosa, P. engelmannii* and *P. leiophylla* in southwestern United States; and *P. caribaea*, *P. engelmannii*, *P. leiophylla*, *P. maximinoi* and *P. oocarpa* in Central America.

BIOLOGY

Adult females lay eggs along S-shaped galleries constructed in the inner bark/sapwood interface (Billings *et al*., 2004). Larvae feed in the inner bark and pupate in chambers near the bark surface. After completing their development, the new adults tunnel their way through the bark, creating small, round exit holes, and fly to new host trees. The beetles introduce a blue-stain fungus which penetrates into the wood interfering with the uptake of water and nutrients and quickly reducing the marketability of the trees (Billings *et al*., 2004). All life stages of the southern pine beetle overwinter beneath or within the bark (Thatcher and Barry, 1982).

Initial attacks are generally on weakened trees; however *D. frontalis* is capable of killing otherwise healthy trees. Other characteristics that contribute to the destructive potential of this beetle include: a rapid life cycle with up to ten overlapping generations per year; the ability of females to establish multiple broods (Payne, 1980); the ability to infest and kill pines of all ages beyond five years as infestations expand, regardless of the physiological condition of the host trees (Lorio, 1980); and infestation cycles that reach peak levels every six to nine years in certain portions of its range.

Once an attack is initiated on the tree trunk, the beetles release aggregation pheromones to attract other individuals of both sexes (Billings *et al*., 2004). Thousands of adult beetles may respond to these pheromones and resin odours, and their concentrated attack overcomes the tree's defence system of resin production. The presence of aggregation pheromones often leads to the attack of trees on the periphery of the infestation by emerging beetles, causing the infestation to rapidly expand and increase tree mortality (Payne, 1980).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Southern pine beetles damage host trees by creating galleries and introducing blue-stain fungi

SYMPTOMS AND DAMAGE

Discoloured tree foliage is often the first indication of beetle attack; needles become yellowish, change to red, and eventually become brown within 1 to 2 months (Thatcher and Barry, 1982). Pines are often killed in groups ranging from a few trees to those covering several hundred acres.

Another typical indication of beetle attack is the presence of pitch tubes, small yellowish-white masses of resin 6 to 13 mm in diameter, on the trunk of host trees which mark the points of beetle attack (Thatcher and Barry, 1982). However, drought-stressed trees may not produce pitch tubes in which case reddish boring dust in bark crevices or at the base of the infested tree may be the only indication of attack.

Characteristic S-shaped egg galleries that cross one another in the inner bark and on the wood surface can be observed upon removal of the bark (Thatcher and Barry, 1982). Adults or larvae may be observed in the galleries or around them if an attack is recent and with time most of the brood can be seen by chipping or shaving the bark (Thatcher and Barry, 1982).

G. ALLARD

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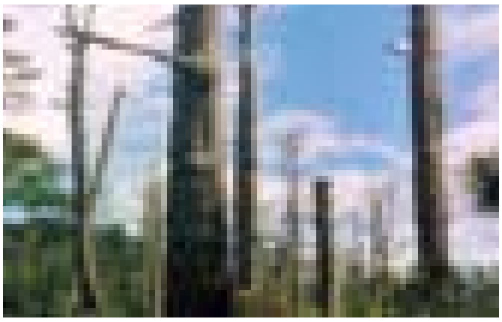

G. ALLARD

Pine trees damaged by the southern pine beetle

In the five years following Hurricane Mitch in 1998, over 100 000 ha of pine forest in Central America were infested mainly with *D. frontalis* in association with other species of *Dendroctonus* and *Ips* spp. The resulting extensive tree mortality severely increased the risk of wildfires and negatively affected wildlife and recreation causing widespread and significant economic impacts.

DISPERSAL AND INTRODUCTION PATHWAYS

Some bark beetles are strong fliers with the ability to migrate long distances. However, the most common pathway of introduction into new areas is through transport of untreated sawn wood and wooden packaging materials with bark on them. Dunnage is also a high risk category of material. If wood is debarked, there is no possibility of introducing bark beetles.

CONTROL MEASURES

The preferred approach for mitigating losses from southern pine beetle attacks is an integrated pest management (IPM) programme involving preventative, detection and control measures (Billings *et al.*, 2004).


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Direct control methods used against the southern pine beetle include cut-and-leave, salvage removal and application of chemical insecticides

Preventative measures include thinning to reduce stand density, removing damaged and weakened trees, and harvesting before trees become overmature. Once an outbreak begins, attention shifts to prompt detection and suppression of individual infestations which can substantially reduce resource loss (Clarke and Billings, 2003). Direct control methods include salvage removal, cut-and-leave, chemical insecticides, and burning infested trees. Cut-and-leave is a technique used solely for *D. frontalis* that consists of felling all trees with fresh attacks or bark beetle broods plus a buffer strip of adjacent uninfested trees and leaving them on site (Billings *et al*., 2004). This procedure reduces beetle survival within infested trees and prevents infestations from growing larger by disrupting pheromone production. Natural enemies, such as diseases, parasites, predators, woodpeckers and weather, may help maintain beetle populations at low levels and bring outbreaks under control.

Dendroctonus frontalis is an A1 quarantine pest for EPPO and member countries are recommended to prohibit the import of *Pinus* commodities from countries where the pest occurs, and optionally also bark of *Pinus* (EPPO/CABI, 1997). If bark is imported, then it is recommended that it be heat-treated or fermented and pine wood from such countries should be debarked, kiln-dried or treated.

Dendroctonus ponderosae

Other scientific names: *Dendroctonus monticolae* Hopkins
Order and Family: Coleoptera: Scolytidae
Common names: mountain pine beetle; bark beetle; Black Hills beetle

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is the most destructive pest of mature pines in North America, lodgepole pine (*Pinus contorta*) in particular. Major outbreaks of this pest have been occurring in western regions of the United States and Canada causing the death of millions of trees. Local climatic changes and increased winter temperatures has exacerbated the problem.

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Adult mountain pine beetle

DISTRIBUTION

Native: North America (Canada, Mexico, United States)
Introduced: No records to date

IDENTIFICATION

Adult *D. ponderosae* are small, black, cylindrical beetles about the size of a grain of rice at 4 to 7.5 mm long. Larvae are legless, creamy-white with light brown heads and about 6 to 7 mm long when fully grown (Langor, 2003). Eggs are smooth, oval, white and translucent.

HOSTS

Primary hosts of the mountain pine beetle are *Pinus contorta* and *P. ponderosa* but *P. albicaulis*, *P. contorta* var. *latifolia*, *P. lambertiana*, *P. monticola*, *P. nigra*, and *P. sylvestris* are also attacked. This pest has also been recorded on *P. aristata*, *P. balfouriana*, *P. coulteri*, *P. edulis*, *P. flexilis*, *P. monophylla* and other pines. *Pseudotsuga menziesii*, *Libocedrus decurrens, Abies* spp., *Larix* spp. and *Picea* spp. such as *Picea engelmannii* are occasionally attacked, particularly near infested pines. These hosts are not used for reproduction, however.

BIOLOGY

Except for a few days during the summer when adults emerge and fly to new host trees, all life stages of the mountain pine beetle are spent under the bark of infested trees. Their life cycle is generally completed in one year although warmer temperatures can result in two generations per year and beetles in high altitudes and cool temperatures may require two years to complete the life cycle (Amman, McGregor and Dolph, 1990).

Female beetles making the first attacks release aggregating pheromones which attract males and other females until a mass attack overcomes the host tree. In mid-summer, adult females attack new host trees by boring through the bark to the sapwood. They construct vertical galleries in the phloem where, after the males join them, they mate and then deposit their eggs. The eggs hatch in 10 to 14 days although it may take longer in cool weather (Amman, McGregor and Dolph, 1990). Larvae feed outwards from the egg galleries on the phloem tissue of the host tree until early fall, overwinter, and continue feeding in the spring (Langor, 2003). Pupation takes place in late spring to early summer and the new beetles feed under the bark for a few days before emerging to fly and attack new host trees in the summer following the initial attack. Adult beetles introduce a blue-stain fungus into the sapwood of the tree that prevents the tree from repelling and killing the beetles with pitch flow (Langor, 2003).

SYMPTOMS AND DAMAGE

Symptoms of attack by *Dendroctonus ponderosae* are first detectable only from the ground and require close examination of trees (Langor, 2003). Conspicuous pitch tubes, masses of red, amorphous resin mixed with bark and wood borings, are produced on the bark surface at the site of attack (Hagle, Gibson and Tunnock, 2003). Pitch tubes may be less obvious on trees suffering from severe drought stress prior to attack (Langor, 2003). Boring dust is also evident in bark crevices and around the base of infested trees.

Removal of the bark from infested trees reveals the characteristic symptoms of a vertical parent gallery with a slight J-like hook at the bottom and evenly spaced larval feeding galleries extending at right angles from the parent gallery (Unger, 1993). One or more life stages may also be present depending on the time since attack (Langor, 2003). The fungi transmitted by adult beetles produce a greyish-blue staining of the sapwood of the host tree which can be observed shortly after a successful attack (Langor, 2003). This fungi blocks the flow of water and nutrients throughout the tree which kills the host tree within a few weeks of successful attack (Langor, 2003).

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Symptoms of attack by the mountain pine beetle: pitch tubes, galleries and blue-stain

During the fall and winter after attack, woodpeckers often feed on bark and wood-boring insects on infested trees. Bark stripped from the tree trunk, particulary in thin-barked hosts such as lodgepole pine, and piles of bark fragments accumulated on the ground at the base of trees are evidence of woodpecker foraging (Hagle, Gibson and Tunnock, 2003; Langor, 2003).

Foliage symptoms are generally not obvious until shortly before the mature adults fly from the tree in the summer following attack.


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Red foliage colour indicative of attack by the mountain pine beetle

The needles of infested trees first turn a faint yellow and then a bright red, which can be mapped in aerial overview surveys (Langor, 2003). Foliage fades to a dull red or reddish-brown in the second year following attack. Three or four years after the initial attack, very little foliage will remain on the host tree.

In addition to the death of trees and forests, outbreaks of *D. ponderosae* upset harvesting plans, reduce the aesthetic values in recreational areas, and increase fire hazard.

Since the first recorded infestations in 1913 in the Okanagan and Merritt areas of Canada, major infestations have occurred regularly killing over 500 million trees by the early 1990s. The current outbreak began to intensify in the northern part of British Columbia's Tweedsmuir Provincial Park in 1993 (CFS, 2007). Successive years of mild winters have allowed the beetle population to grow and spread further each year through the lodgepole pine forests making the current outbreak the largest ever recorded in North America. The large numbers of dead and dying trees have also increased the risk of wildfires. It has been predicted that if the beetle continues to spread at its current rate, as much as 80 percent of mature pine will be dead by 2013 (CFS, 2007).

DISPERSAL AND INTRODUCTION PATHWAYS

Bark beetles are strong fliers with the ability to migrate long distances. The most common pathway of introduction into new areas is through transport of untreated sawn wood and wood packaging materials with bark on them. If wood is debarked, there is no possibility of introducing bark beetles.

CONTROL MEASURES

The options available for controlling *Dendroctonus ponderosae* depend somewhat on the size of the outbreak, the age of the stand, the size of host trees, and the site conditions. Current approaches to the present outbreak include preventative management to reduce tree, stand and landscape susceptibility and direct control strategies such as logging infested and dead trees (Langor, 2003).

Silvicultural control measures, such as thinning stands, patch cutting, selective harvesting and salvage logging, are the most efficient (Amman, McGregor and Dolph, 1990; Langor, 2003). Some other direct control measures include felling and burning trees and debarking.

To provide a temporary control measure that slows infestations, insecticides are available. However if beetle outbreaks are large, chemical control is not cost effective (Amman, McGregor and Dolph, 1990; Langor, 2003). Preventive spraying can help protect individual high-value trees.

Baiting and trapping with synthetic beetle attractants can help manipulate and monitor small outbreaks by localizing infestations and preventing spread into susceptible stands (Amman, McGregor and Dolph, 1990).


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Silvicultural measures used to control the mountain pine beetle include thinning and felling of infested trees

Natural enemies of this pest species include woodpeckers, nematodes, predaceous insects, such as *Enoclerus sphegeus*, *Laphria gilva*, *Lonchaea* sp., *Medetera aldrichii*, *Temnochila chlorodia*, *Thanasimus undatulus* and *Xylophagus* sp., and parasitic insects, such as *Coeloides dendroctoni*, *Dinotiscus burkei* and *Roptrocerus eccoptogastri* (Bellows, Meisenbacher and Reardon, 1998). These natural enemies are likely most important in limiting or controlling the pest at low populations; during outbreaks, they appear less able to exert sufficient limits on the population.

Dendroctonus ponderosae is an A1 quarantine pest for EPPO and member countries are recommended to prohibit the import of *Pinus* commodities from countries where the pest occurs, and optionally also bark of pines (EPPO/CABI, 1997). If bark is imported, then it is recommended that it be heat-treated or fermented and pine wood from such countries should be debarked, kiln-dried or treated.

Dendroctonus valens

Other scientific names: *Dendroctonus rhizophagus*
Order and Family: Coleoptera: Scolytidae
Common names: red turpentine beetle; bark beetle

The red turpentine beetle, *Dendroctonus valens* LeConte, is a common pest of forest, shade and park trees of pole size or larger. It is native to North America and was accidentally introduced into China in the 1980s presumably on unprocessed logs imported from the western United States. Red turpentine beetles can be distinguished from engraver beetles by their larger size, reddish-brown colour and the presence of large, pinkish brown to white pitch tubes, a mixture of pine sap and beetle boring dust, on the lower trunk of infected hosts.

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Adult red turpentine beetle, Dendroctonus valens

DISTRIBUTION

Native: Latin America and the Caribbean: portions of Central America, Mexico (Wood, 1982)
North America (Wood, 1982)
Introduced: Asia and the Pacific: China (mid 1980s)

IDENTIFICATION

Eggs are shiny, opaque white, ovoid cylindrical, and a little over 1 mm in length (Smith, 1971). Larvae are grublike, legless and white with a brown head capsule and a small brown area at the hind end (Smith, 1971). A row of small, pale-brown tubercles develop along each side of the body. Full grown larvae are approximately 10 to 12 mm long. Pupae are white and slightly shorter than the larvae.

Adult beetles are typically long and stout, about 6 to 10 mm long and dark brown to black in colour with reddish-brown wing covers (Smith, 1971; Hagle, Gibson and Tunnock, 2003).

HOSTS

In its native range, hosts include: *Pinus* spp., including *P. resinosa*, *P. contorta*, *P. banksiana*, *P. strobes*, *P. rigida*, *P. echinata*, *P. radiata*, and *P. ponderosa*; *Picea* spp.; *Larix* spp.; *Abies* spp.; and *Pseudotsuga menziesii.* In its introduced range in China, hosts are primarily *Pinus tabulaeformis* and *P. armandii* and occasionally *Picea* and *Abies* species.

BIOLOGY

Peak flight and activity usually occur in the spring when adult beetles emerge from recently cut stumps and dying trees to attack trees, exposed roots, or freshly cut stumps (Smith, 1971). The female beetle bores through the bark to the surface of the wood where she is soon joined by a male. Typically one pair of beetles is found in an individual gallery but occasionally there may be one, three, or four beetles present. Resin mixed with boring particles and frass is pushed to the outer bark surface forming a pitch tube or dropping in pellets to the base of the tree (Smith, 1971).

Eggs are deposited on alternate sides of the gallery (Hagle, Gibson and Tunnock, 2003). The egg mass can extend from one to several inches along the gallery and the number of eggs it contains varies from a few to more than a hundred (Smith, 1971). The adult beetles continue to feed in the gallery for several weeks and then they either bore out through the bark and make additional attacks or die within the gallery. The eggs hatch in 1 to 3 weeks during the summer months.

Larvae feed gregariously in the phloem often forming fan-shaped galleries. Larvae are present for two summers after which they pupate and then overwinter the second year as adults beneath the bark (Hagle, Gibson and Tunnock, 2003). In standing trees, adults briefly emerge in their second fall and re-enter the tree to overwinter beneath the bark at the root collar where they are protected from the elements.

The rate of development and the number of generations per year are largely dependent on temperature (Smith, 1971). In warmer regions there is at least one generation per year while in northern areas at high elevations two years may be required for a single generation. In southern areas at low elevations, there may be as many as three generations per year.

SYMPTOMS AND DAMAGE

The red turpentine beetle usually attacks trees of reduced vigour or those infested with other bark beetles, but it can attack healthy trees. It is often found in association with other bark and wood-boring beetles such as *Ips* spp. and other *Dendroctonus* spp.

Attacks on standing trees are concentrated on the lower trunk and exposed roots. Large reddish-white pitch tubes on the bark or pellets on the ground around the base of host trees from mid-May to July are usually the first sign of infestation (Hagle, Gibson and Tunnock, 2003). Feeding by larvae and adults in galleries can completely girdle the trees resulting in death although this is not always the case. Host trees are inoculated with blue-stain fungi. Freshly cut logs with thick bark may be attacked and while they will not produce large numbers of beetles, they can multiply and threaten nearby trees (Smith, 1971). Attacks, especially on healthy trees, may last for two years or more. Severe attacks can kill trees.

Despite the abundance and wide distribution of *D. valens*, outbreaks have not been extensive or severe in the United States (Smith, 1971). The beetle has been found most frequently in individual trees or in groups of trees in localized areas. In China, however, it is considered an aggressive and very destructive pest of *Pinus tabuliformis*, China's most widely planted pine species. It was first detected in Shanxi Province in 1998 and widespread tree mortality was reported in 1999; this outbreak continues and has spread to three adjacent provinces causing unprecedented tree mortality (Yan *et al*., 2005).

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Pitch tubes evident on a host tree infested with Dendroctonus valens

DISPERSAL AND INTRODUCTION PATHWAYS

The beetles are strong fliers capable of flying more than 10 miles (Smith, 1971). This species can also be introduced into new areas on forest products and wood packaging materials as evidenced by its arrival in China in the 1980s.

CONTROL MEASURES

Once attacked a tree typically cannot be saved therefore preventive measures such as maintaining the health and vigour of forest stands by thinning or removal of overmature trees are the best tactics to reduce the impacts of this pest. Chemicals have been used in some areas and have been shown to help prevent attacks and kill beetles already beneath the bark.

In China, a variety of methods from informal surveys to the use of baited traps are used to detect and monitor *Dendroctonus valens* populations. In addition, investigations are underway on the use of the predator *Rhizophagus grandis* for biological control.

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Damage caused by Dendroctonus valens *in the United States (left) and Shanxi Province, China (right)*

Dendrolimus sibiricus

Other scientific names: *Dendrolimus laricus* Tschetverikov; *Dendrolimus superans sibiricus* Tschetverikov
Order and Family: Lepidoptera: Lasiocampidae
Common names: Siberian caterpillar; Siberian silk moth; Siberian moth; Siberian conifer silk moth; Siberian coniferous silk moth; Siberian lasiocampid; larch caterpillar

Widespread on the Asian continent, *Dendrolimus sibiricus* Tschetverikov is a destructive pest of conifers causing significant defoliation of trees in both naturally regenerated and planted forests. It is able to attack and kill healthy trees and it has been known to kill forests across very wide areas.

Dendrolimus sibiricus *life cycle stages: eggs, larva, pupae, adult*

DISTRIBUTION

Native: Asia and the Pacific: Democratic People's Republic of Korea, Kazakhstan, Mongolia, People's Republic of China, Republic of Korea,
Europe: Russian Federation
This pest is believed to have originated in Siberia.
Introduced: No record to date but this pest poses a real threat

IDENTIFICATION

Adult Siberian moths are yellowish-brown or light grey to dark brown or almost black. The forewings are marked by two characteristic dark stripes and a white spot in the centre. Hind wings are the same colour as the forewings but lack markings. Females are approximately 40 mm long with a wing span of 60 to 80 mm while males are approximately 30 mm long with a 40 to 60 mm wing span (Kimoto and Duthie-Holt, 2006; EPPO, 2005).

Larvae are mainly black or dark brown with numerous spots and long hairs. They are 55 to 70 mm long and the second and third segments are marked with blue-black stripes (Kimoto and Duthie-Holt, 2006). Reddish setae are found on the sides of larvae, usually as red jagged bands or spots.

Eggs are oval, 2.2 mm long and 1.9 mm wide. Initially light-green in colour, they turn creamy-white and darken and become spotted over time (Kimoto and Duthie-Holt, 2006; EPPO, 2005).

HOSTS

Larix spp., including *L. gmelinii* and *L. sibirica*; *Pinus* spp., including *P. sibirica* and *P. koraiensis*; *Abies* spp., including *A. sibirica* and *A. nephrolepis*; *Picea* spp., including *P. ajanensis* and *P. obovata*; and *Tsuga* spp.

BIOLOGY

Spring flight usually occurs in mid-July. Immediately after mating, females lay eggs on the needles primarily in the lower part of the crown although during outbreak years, eggs are laid throughout the tree and on the surrounding ground. One egg mass may contain 1 to 200 eggs (Kimoto and Duthie-Holt, 2006; EPPO, 2005). Each female lays an average of 200 to 300 eggs, with a maximum of 800 (EPPO, 2005). Egg development typically takes 13 to 15 days with an occasional maximum of 20 to 22 days (EPPO, 2005).

There are 6 to 8 larval instars. First instar larvae eat the edges of needles and moult in 9 to 12 days while second instar larvae cause further damage to the needles and develop for 3 to 4 weeks before moulting (EPPO, 2005). The third instar larvae descend to the soil in September and overwinter in the top layers of soil. In the spring of the following year, the larvae return to the crowns to feed, eating complete needles and sometimes the bark of young shoots and cones. They moult after one month and again at the end of July or in August. In autumn, the larvae return to the soil and overwinter for a second time.

In the following spring, when the temperature of the forest floor rises to 3.5 to 5.0 °C, the larvae break diapause and ascend to the tree crowns to resume feeding. During this period, they eat about 95 percent of the food they need for development and it is then that the major damage occurs (Orlinski, 2000). Larvae finish maturation feeding by late June or early July and pupate in the crowns of trees where they form silken cocoons intertwined with foliage and branches. The pupal stage last from 18 to 22 days after which the adults emerge and the cycle begins again.

The full life cycle usually takes two years. However in southern parts of its native range one generation can develop in a single year while in northern regions it may take up to three years (Orlinski, 2000). Drought, increasing population density and other factors cause some larvae to have a shorter, two calendar-year life cycle. As a result, the adults of two generations emerge simultaneously and the population increases sharply. Competition for food may extend larval development and increase the number of instars.

Outbreaks of this moth are cyclic, occurring every 8 to 11 years following a few years of water shortage and last for 2 to 3 years. The period between outbreaks is becoming shorter partly due to changing climate.

SYMPTOMS AND DAMAGE

The Siberian caterpillar causes significant defoliation of both naturally regenerated and planted forests. It is able to attack and kill healthy plants and it has been known to kill trees and forests across very wide areas. Death of forests can be caused directly by defoliation or indirectly by increasing the susceptibility of the forest to subsequent attack by other forest pests such as bark beetles or forest fires (Orlinski, 2000). Other effects of *D. sibiricus* attack include the loss of vigour, reduction in growth, and reduced seed crops.

The duration and effect of outbreaks depends on the forest type (Ghent and Onken, 2004). Outbreaks in fir and five-needled pines result in defined focal areas with very high densities of larvae that defoliate trees for two or three successive years before the outbreak collapses. Tree mortality is virtually 100 percent in many stands. Outbreaks in larch forests are more prolonged but cause less tree mortality. Moths migrate from defoliated larch hosts to new areas to lay eggs. As a result, successive years of severe defoliation rarely occur and the outbreak population becomes dispersed.

As well as the impact on trees and forests, Siberian caterpillars have stinging hairs that can cause significant allergic reactions in people living near and visiting forests as well as forest workers. Exposure to the larval hairs or secretions of the Siberian caterpillar produces severe dermatitis as well as systemic reactions affecting the joints and other parts of the body.

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*Siberian larch (*Larix sibirica*) defoliated by the Siberian caterpillar, Mongolia*

DISPERSAL AND INTRODUCTION PATHWAYS

Adults are strong fliers and can spread fairly rapidly. Pathways of introduction include natural movement of adults and the movement of eggs on nursery stock or forest products.

CONTROL MEASURES

Ground and aerial application of chemical and bacterial insecticides, such as *Bacillus thuringiensis* var *kurstaki* (Btk), has been used to control *Dendrolimus sibiricus* in countries within the native range of the pest.

Natural enemies of the Siberian caterpillar, including several parasitoids and pathogens, play an important role in the regulation of population density. Examples include the egg parasitoids *Telenomus gracilis*, *T. tetratomus*, and *Trichogramma dendrolimi*; the larval and pupal parasitoids *Ooencyrtus pinicolus* and *Rhogas dendrolimi*; the bacteria *Bacillus dendrolimus* and *B. thuringiensis*; the fungus *Beauveria bassiana*; and some viruses (Orlinski, 2000; EPPO, 2005).

In 2002, *D. sibiricus* was added to the EPPO A2 action list and it has been recommended that EPPO member countries regulate it as a quarantine pest. Since *D. sibiricus* is apparently slowly spreading westwards through Europe, carrying out surveys using pheromone traps and applying appropriate control measures in areas at the border of the pest's present range would help avoid the possible introduction of this pest into new areas (EPPO, 2005).

To prevent the introduction of *D. sibiricus*, it is recommended that: commodities, plants for planting and cut branches of host plants from infested areas should be free of soil; commodities should originate in a pest-free area, be produced in protected houses, fumigated, or be imported during winter; and wood should be debarked, heat-treated, originate in a pest-free area, or be imported during winter, and isolated bark should be treated to destroy any insects (EPPO, 2005).

Gonipterus scutellatus

Order and Family: Coleoptera: Curculionidae
Common names: eucalyptus weevil; eucalyptus snout beetle

Gonipterus scutellatus Gyllenhal, 1833 is a leaf-feeding beetle that is a major defoliator of eucalypts. It is indigenous to Australia but occurs in many countries throughout the world where eucalypts are grown. Infestations of this beetle are known to cause serious damage. This pest is a major threat worldwide as it continues to spread, both within continents where it currently occurs and to previously uninfested continents.

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Adult Gonipterus scutellatus

DISTRIBUTION

Native: Asia and the Pacific: Australia
Introduced: Africa: Kenya, Lesotho, Madagascar, Malawi, Mauritius (1940), Mozambique, South Africa (1916), St. Helena, Swaziland, Uganda, Zimbabwe
Asia and the Pacific: New Zealand, People's Republic of China
Europe: France (1977), Italy (1975), Portugal (1990s), Spain (1991)
Latin America and the Caribbean: Argentina, Brazil, Chile, Uruguay
North America: United States (1990s)

IDENTIFICATION

Approximately 12 to 14 mm in length, adult eucalypt weevils vary in colour from grey to reddish-brown with a light, transverse band on the back and are covered by small pale brown hairs (Phillips, 1992). It is very similar to the Australian gum tree weevil, *Gonipterus gibberus*.

Larvae are approximately 10 to 14 mm long, yellowish-green in colour with black spots and a black stripe running along each side of the body (Phillips, 1992; EPPO, 2005). They often have a characteristic long thread of faecal material coiled up behind them.

Eggs are laid in greyish or blackish-brown coloured capsules on both surfaces of the leaves (Phillips, 1992). These capsules are approximately 3 mm in length, 2 mm high and 1.5 mm in width and contain 3 to 16 pale yellow eggs arranged in vertical layers.

HOSTS

Eucalyptus spp., including *E. camaldulensis*, *E. cornuta*, *E. globulus* ssp. *globulus*, *E. grandis*, *E. kirtoniana*, *E. longifolia*, *E. maidenii* ssp. *globulus*, *E. obliqua*, *E. propinqua*, *E. punctata*, *E. robusta*, *E. smithii*, *E. tereticornis*, *E. urnigera* and *E. viminalis.*

Differences in susceptibility exist among eucalypt species (Rivera and Carbone, 2000). In Mauritius, *E. robusta*, *E. tereticornis* and *E. kirtoniana* are the most susceptible eucalypt species while in Kenya, *E. globulus* ssp. *globulus*, *E. maidenii* ssp. *globulus*, *E. robusta* and *E. smithii* are the most commonly attacked and *E. saligna* and *E. citriodora* are known to be practically immune. In Madagascar, the most susceptible species were *E. cornuta*, *E. viminalis*, *E. punctata*, *E. globulus* ssp. *globulus*, *E. urnigera* and *E. camaldulensis*; in Spain, *E. globulus* ssp. *globulus* and *E. obliqua* were most commonly attacked; and in Italy, *G. scutellatus* showed a clear preference for the leaves of *E. globulus ssp. globulus* and did not attack *E. cinerea*, *E. gunnii*, *E. polyanthemos*, *E. stuartiana* and *E. rostrata*. Another report from Spain reported that *G. scutellatus* exhibited a clear preference for *E. globulus ssp. globulus*, *E. longifolia*, *E. grandis* and *E. propinqua* and completely avoided other species although they noted that less palatable species might be used by the insect if preferred species were absent (Rivera and Carbone, 2000).

BIOLOGY

Females mate several times and lay their eggs in batches covered by a capsule on both surfaces of new leaves.

They continue to lay eggs, up to 21 to 33 capsules, throughout a lifetime of about 91 days (EPPO, 2005). Eggs hatch in 3 to 4 weeks and the larvae feed on leaves and twigs and then pupate in the soil. Adults also feed on leaves and growing shoots.

There is usually more than one generation per year, with females living for about three months and larval development taking between 30 and 80 days. In some places there are continuous generations.

SYMPTOMS AND DAMAGE

Adults and larvae feed on the leaves of host trees but it is the larval stage that does the most damage. They cause damage by eating only one surface of the leaves, leaving characteristic tracks while adults chew the edges of the leaves giving them a ragged, scalloped appearance (Phillips, 1992). Both adults and larvae prefer the newly expanded adult leaves and shoots. Such feeding can result in dieback of shoot tips and development of tufts of epicormic shoots (EPPO, 2005).

Severe infestations and successive defoliations by this beetle can cause tree mortality, reduction in growth, coppicing and stunting of trees, although some *Eucalyptus* spp. are more susceptible to damage than others. Young trees are the most susceptible but seedlings may also be attacked.

DISPERSAL AND INTRODUCTION PATHWAYS

Dispersal is by adult flight, adults hitch-hiking on non-plant material, and movement of infested plant material or soil.

CONTROL MEASURES

Biological control of this species by means of the importation of *Anaphes nitens* (Hymenoptera: Mymaridae), an egg parasitoid, has been highly successful in many areas. Where the biological control of *G. scutellatus* is unsuccessful, the alternative is to use tolerant host plant species (Rivera and Carbone, 2000). Chemical treatment is not recommended because of the potential danger to beneficial honey bees attracted to the flowers of eucalypt species (EPPO, 2005).

Gonipterus scutellatus is an A2 quarantine pest for EPPO and is also of phytosanitary significance for COSAVE. It is regulated by most EPPO countries, in particular by the EU, and recommended measures require that *Eucalyptus* plants for planting (except seeds) and cut branches should come from a pest-free area or plants should be free from soil and treated against *G. scutellatus* (EPPO, 2005).

Heteropsylla cubana

Other scientific names: *Heteropsylla incisa* Sulc.
Order and Family: Hemiptera: Psyllidae
Common names: leucaena psyllid

Heteropsylla cubana Crawford, 1914 is a significant pest of *Leucaena leucocephala*, a tree grown extensively in community forestry and agroforestry ecosystems for fodder and fuelwood throughout the tropics, causing defoliation, wilting, dieback, and in some cases, tree death. It is native to Central and South America but has dramatically spread from its native range, across the Pacific Ocean to Asia and the Pacific and Africa in less than 10 years. In many countries where leucaena has been introduced it is now considered a highly invasive tree. As a result, *H. cubana* may be considered more of a biological control agent than a forest pest.

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Infestation of the leucaena psyllid, Heteropsylla cubana, *near Mombasa, Kenya*

DISTRIBUTION

Native: Latin America and the Caribbean
Introduced: Africa: Burundi (1992), Ethiopia (1993), Kenya (1992), Malawi (1994), Mauritius (1991), Mozambique (1993), Réunion (1991), Sudan (1994), the United Republic of Tanzania (1992), Uganda (1992), Zambia (1994)
Asia and the Pacific: Australia (1986), Bangladesh (1987), Cambodia (1986), China (1986), Cook Islands (1985), Fiji (1985), Guam (1985), India (1988), Indonesia (1986), Malaysia (1986), Myanmar (1986), Nepal (1987), New Caledonia (1985), Papua New Guinea (1985), the Lao People's Democratic Republic (1986), Philippines (1985), Singapore (1986), Solomon Islands (1985), Sri Lanka (1987), Tahiti (1985), Thailand (1986), Tonga (1985), Viet Nam (1986)
North America: United States (1993)

IDENTIFICATION

Adult psyllids are aphid-like, approximately 2 mm in length, winged and light green to yellow in colour. If disturbed, they use stout legs to jump before taking flight. Nymphs are similar to adults in appearance except they are smaller, wingless and remain on the plant if disturbed. They undergo five instars over 8 to 9 days (Moog, 1992). Eggs can be barely seen with the naked eye primarily on young terminal leaves; in large numbers they appear as orange-yellow masses.

HOSTS

Leucaena spp. in particular *Leucaena leucocephala*, but also *L. trichodes*, *L. pulverulenta*, *L. diversifolia*, *L. salvadorensis* (Nair, 2001); *Albizia* spp.; *Mimosa* spp.; *Samanea saman*

BIOLOGY

Females begin laying eggs 1 to 3 days after becoming adults (Moog, 1992). Eggs are laid on and between new leaves on young shoot tips and hatch in 2 to 3 days. The insect is most common on young growth where eggs, nymphs and adults often occur together (Hertel, 1998). The cycle from egg to adult takes 10 to 20 days. Psyllids prefer high relative humidity and temperatures in the 20s (°C). Adults feed on young growth and occasionally older growth and flowers.

SYMPTOMS AND DAMAGE

Adults and nymphs suck the sap of the terminal leaves, buds and flowers of host plants which reduces flower and seed production and causes new shoots and foliage to become stunted and deformed rendering the foliage useless for fodder or human consumption. In addition, honeydew produced by the psyllids permits the growth of sooty moulds which prevents light from reaching the leaf surfaces thereby reducing photosynthesis and plant production. Repeated attacks cause wilting, defoliation, branch dieback or death of host trees (Hertel, 1998).

Leucaena psyllid damage, Kenya

DISPERSAL AND INTRODUCTION PATHWAYS

The quick and impressive spread of leucaena psyllid, over large areas and regions has led to speculation that wind dispersal plays a major role as opposed to human-assisted dispersal (Ciesla, 1998).

CONTROL MEASURES

Measures aimed at controlling the leucaena psyllid have primarily concentrated on the development of resistant leucaena varieties and the use of biological control agents. Biological control agents for the leucaena psyllid include the predators, *Curinus coeruleus* and *Olla v-nigrum* (Coleoptera: Coccinellidae), and the parasitoids, *Psyllaephagus yaseeni* (Hymenoptera: Encyrtidae) and *Tamarixia leucaenae* (Hymenoptera: Eupelmidae) (FAO, 1998).

Hypsipyla grandella and *Hypsipyla robusta*

***Hypsipyla grandella* Zeller, 1848**
Order and Family: Lepidoptera: Pyralidae
Common names: mahogany shoot borer

***Hypsipyla robusta* Moore, 1886**
Other scientific names: *Epicrocis terebrans* Oliff, 1890; *Magiria robusta* Moore, 1886; *Hypsipyla scabrusculella* Ragonot, 1893; *Hypsipyla pagodella* Ragonot, 1888
Order and Family: Lepidoptera: Pyralidae
Common names: mahogany shoot borer; cedar tip moth; toon shoot fruit borer

Hypsipyla shoot borers are a significant threat to many high value timber species belonging to the Meliaceae and Verbenaceae, including species of *Swietenia*, *Khaya*, *Toona, Tectona* and *Cedrela*. The two most important *Hypsipyla* species are *H. grandella* in the Americas, and *H. robusta* in areas of Africa and Asia and the Pacific.

DISTRIBUTION

Hypsipyla grandella

Native: Latin America and the Caribbean: Central America, the Caribbean, Mexico, South America (except Chile)
North America: United States (southern Florida)
Introduced: The introduced range is not verified, but it is known from Mauritius (Africa).

Hypsipyla robusta

Native: Africa (West and East); Asia and the Pacific
Introduced: The introduced range is not verified.

IDENTIFICATION

Adults are brown to greyish-brown in colour with a wingspan of approximately 23 to 45 mm (Howard and Merida, 2005). The forewings are grey to brown with shades of rusty red on the lower portion and whitish scales with black dots toward the wing tips (Howard and Merida, 2005). Wing veins are distinctively overlaid with black. Hind wings are white to translucent with dark-coloured margins.

Larvae are tan to white in colour, turning bluish in later instars, with a brown head capsule (Howard and Merida, 2005). Mature larvae are approximately 25 mm long.

Pupae are brownish-black and enclosed in a silken cocoon (Howard and Merida, 2005).

Eggs are oval, dorsoventrally flattened, and measure 0.5 to 1.0 mm by 0.5 to 0.98 mm (Griffiths, 2001; Howard and Merida, 2005). When first laid they are white in colour and if fertilized, they develop distinct red and white banding within 24 hours.

HOSTS

Hypsipyla grandella

Meliaceae and Verbenaceae: *Swietenia* spp. (*S. macrophylla*, *S. mahagoni*); *Cedrela* spp.; *Tectona* spp.; *Toona* spp. (*T. australis*, *T. ciliata*); *Chukrasia tabularis*

Hypsipyla robusta

Meliaceae and Verbenaceae: *Swietenia* spp. (*S. macrophylla*, *S. mahagoni*); *Cedrella* spp. (*C. toona*); *Tectona* spp. (*T. grandis*); *Toona* spp. (*T. australis*, *T. ciliata*); *Chukrasia tabularis*; *Khaya* spp.; *Carapa procera*; *Entandrophragma* spp.; *Lovoa trichiliodes*

BIOLOGY

Females mate only once and lay 200 to 450 eggs over a period of five to eight days. On young trees, eggs are deposited singly or occasionally in clusters of 3 to 4 on the shoots, stems and leaves, particularly the upper leaf surface. Concentrated around the growing shoots, eggs may occur at all heights on the host tree and are often placed in concealed locations such as leaf axils, leaf scars, veins, lenticels and fissures in the bark (Griffiths, 2001). Eggs laid on fruit are initially deposited singly on the fruit surface but are later laid in clumps of up to 12 among the frass and webbing associated with existing damage to the fruit (Griffiths, 2001).

After three to five days, the eggs hatch and the larvae tunnel in the developing shoots of young trees and sometimes also feed upon the flowers, fruit and bark of host trees (Griffiths, 2001). They pupate either in the twigs, shoots or the soil.

A generation usually takes 1 to 2 months but may extend to five months if larvae enter diapause, which has been reported from areas of low temperature or rainfall, and occurs immediately after fruit-feeding despite apparently suitable climatic conditions (Griffiths, 2001). Adults are typically nocturnal and mate within six days of emergence.

SYMPTOMS AND DAMAGE

Hypsipyla caterpillars attack seed and fruit capsules and bore into the tips, shoots and twigs of several high quality timber species killing the first few centimeters. The caterpillars destroy the terminal shoot causing the tree to form many side branches and frequently a deformed trunk thereby significantly reducing the economic value of the timber (Griffiths, 2001). Growth rate is reduced and heavy and repeated attacks can result in tree death.

This species mainly attacks trees in areas with high light, hence the biggest effects are observed in young planted forests, particularly those planted with a single species (Nair, 2001). Young understorey trees in naturally regenerated forests suffer far less damage. The borer is a problem to both nursery and planted stock; trees from three months to fourteen years in age and between 50 cm and 15 m in height have shown symptoms of *Hypsipyla* attacks (Griffiths, 2001). It has been one of the main factors preventing the ready establishment of mahogany plantations in many areas.

DISPERSAL AND INTRODUCTION PATHWAYS

Adults are strong fliers and can travel considerable distances to locate suitable host material.

CONTROL MEASURES

Hypsipyla grandella and *H. robusta* have proven difficult to control. While some methods can significantly reduce populations, this pest can cause significant damage even at low population levels and it is therefore considered a major destructive forest pest. Three main control methods are considered to control *Hypsipyla* species: silvicultural, chemical and biological.

Silvicultural techniques applied to control *Hypsipyla* species include mixed or enrichment plantings, varying tree density, provision of shade, promoting vigourous tree growth in nurseries and plantations, and the selection of resistant or tolerant host trees.

In a review of research on the chemical control of *Hypsipyla* spp., Wylie (2001) noted that there is no single reliable, cost-effective, and environmentally sound chemical pesticide available to control these insects and suggested that chemical control of these pests might be most applicable in nursery situations or as part of an integrated pest management programme by temporarily reducing populations in limited areas.

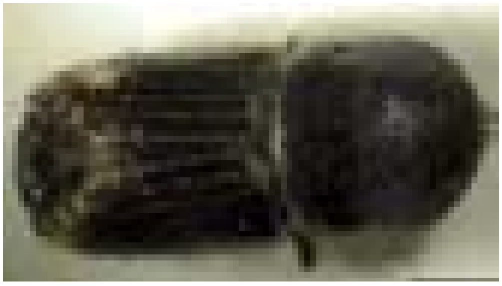
Though *H. robusta* and *H. grandella* are attacked by a range of natural enemies, they have not been shown to reduce the larval abundance and subsequent damage to acceptable levels (Sands and Murphy, 2001). Previous attempts at biological control of *Hypsipyla* species have not been successful although research into possible agents continues.

The most promising strategies for management of *Hypsipyla* species are integrated pest management programmes involving a combination of these techniques such as the use of pest tolerant host trees, planting of mixed stands and providing shade.

Ips sexdentatus

Other scientific names: *Dermestes sexdentatus* Börner; *Bostrichus pinastri* Bechstein; *Tomicus stenographus* Duftschmidt; *Ips typographus* De Geer
Order and Family: Coleoptera: Scolytidae
Common names: six-spined engraver beetle; six-toothed bark beetle; twelve-spined ips; pine stenographer beetle

Ips sexdentatus Börner, 1767 is a pest of conifer tree species in its native range of Asia and Europe. While it typically attacks stressed or weakened trees it has been known to attack and cause the death of healthy trees of commercial importance.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Ips sexdentatus *adults and galleries*

DISTRIBUTION

Native: Asia and the Pacific (mainland); Europe
Introduced: No records to date

IDENTIFICATION

At approximately 5.5 to 8.2 mm in length, *Ips sexdentatus* is the largest species of its genus (Cavey, Passoa and Kucera, 1994; Kimoto and Duthie-Holt, 2006). They are cylindrical, robust, shiny, brown or brownish-black beetles with erect yellow hairs protruding from the body. The head is covered by a thoracic shield and is not visible when viewed dorsally (Kimoto and Duthie-Holt, 2006). This beetle is named for the six spines or teeth found on each side of the posterior portion of the forewings (Cavey, Passoa and Kucera, 1994).

HOSTS

Pinus spp., including *P. brutia*, *P. heldrichii*, *P. nigra*, *P. pinaster* and *P. sylvestris*; *Abies* spp., including *A. alba* and *A. normanndiana*; *Larix* spp., including *L. decidua* and *L. sibirica*; *Picea* spp., including *P. abies* and *P. orientalis*; *Pseudotsuga menzeisii*

BIOLOGY

Attacks are initiated by the males, who construct nuptial chambers under the bark, emit aggregation pheromones and are subsequently joined by 2 to 5 females (Kimoto and Duthie-Holt, 2006). After mating, each female constructs a longitudinal egg gallery, typically 15 to 35 cm long and 4 to 5 mm wide, and deposits eggs in individual niches along each side of the gallery.

Young larvae feed in galleries perpendicular to the egg galleries which are usually found in the inner bark of the lower stem. Larval galleries increase in size as the larvae grow. Pupation takes place in round chambers constructed at the ends of the larval galleries. Adults require maturation feeding before reaching sexual maturity. Round exit holes measuring approximately 4 mm in diameter are apparent on the tree trunk after adults emerge (Kimoto and Duthie-Holt, 2006).

The number of generations per year and the timing of the life cycle depend on climate. This insect typically has two generations per year, one generation north of the Arctic Circle, with adult flight periods from April to May and July to August. In the Mediterranean region and other areas with a long, warm summer season, *I. sexdentatus* can undergo four to five generations (EPPO/CABI, 1997).

SYMPTOMS AND DAMAGE

Ips sexdentatus is considered a secondary pest, often found in association with other forest pests such as *I. acuminatus* and *Tomicus piniperda*, that usually attacks trees that have been otherwise stressed or weakened and occasionally attacks freshly felled trees or windthrown trees (EPPO/CABI, 1997). It prefers to attack large trees with thick bark. It rarely attacks healthy, vigorously growing trees though it is capable of killing trees of commercial importance.

Breeding attacks by *Ips sexdentatus* are characterized by the presence of reddish-brown frass on the bark surface of host trees, freshly cut logs or windthrow (Kimoto and Duthie-Holt, 2006). If healthy, vigourous trees are attacked, pitch tubes can be found on the main stem (Kimoto and Duthie-Holt, 2006). The needles of attacked trees turn from green to yellow and then reddish-brown. As with other conifer bark beetle species, *Ips sexdentatus* is a vector for blue-stain fungi (*Ophiostoma* spp.) which hastens the death of trees, discolours the wood and can result in loss of lumber grade and value.


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Damage caused by Ips sexdentatus*: L, pitch tubes; R, discoloured needles of Austrian pine (*Pinus nigra*), France*

DISPERSAL AND INTRODUCTION PATHWAYS

Adult *Ips* beetles are capable of flying up to 4 km in search of suitable host material and they are also subject to wind dispersal. Transport of unprocessed logs, wood products, wooden packing materials, dunnage or pallets containing bark strips can provide a means of introduction of immature stages and adults.

CONTROL MEASURES

The most effective control measure against damage by *Ips sexdentatus* is to remove infested trees before the new generation of adult beetles emerges (EPPO/CABI, 1997). Debarking infested trees may also help to prevent further infestations. The use of trap trees may be helpful in controlling high density populations.

Ips subelongatus

Other scientific names: *Ips fallax* Eggers
Order and Family: Coleoptera: Scolytidae
Common names: larch bark beetle; larch engraver beetle; oblong bark beetle

Ips subelongatus Motschulsky, 1860 is considered to be the most destructive bark beetle pest of larch within its natural range. It is considered by many to be of equal importance to the European spruce bark beetle, *Ips typographus*, which is generally regarded as Europe's most damaging bark beetle.

DISTRIBUTION

Native: Asia and the Pacific (mainland)
Europe: Russian Federation
Introduced: No reports to date

IDENTIFICATION

Adult beetles are completely brown in colour and have an elongated body approximately 4.5 to 6.0 mm long (Kimoto and Duthie-Holt, 2006). The posterior end of the forewings is completely covered with long hairs and also has four spines on each side, the third of which has a characteristic bulge at the top (Kimoto and Duthie-Holt, 2006).

Eggs are round and pearly white in colour. The larvae are white grubs with amber coloured head capsules that are typically 4 to 5 mm long when mature (Orlinski, 2004).

HOSTS

Larix spp., including *L. sibirica*, *L. gmelinii*, *L. leptolepis* and *L. olgensis*; *Abies* spp.; *Picea* spp.; *Pinus* spp., including *P. sylvestris*, *P. sibirica* and *P. koraiensis*

BIOLOGY

In the southern part of its distribution, the first spring mass flight usually occurs from mid-May to the end of June, when midday temperature reaches 16 to 20 °C, and lasts for 15 to 17 days (EPPO, 2005). Attacks are initiated by the males, who construct nuptial chambers under the bark, emit aggregation pheromones and are subsequently joined by 2 to 5 females (Kimoto and Duthie-Holt, 2006). After mating, each female constructs an egg gallery, typically 16 to 18 cm long and 3 to 3.5 mm wide, and deposits her eggs. The shape and depth of egg galleries varies depending on the health of the host tree; in healthy trees, they radiate downwards and upwards from the nuptial chamber but in stressed trees they radiate vertically and horizontally (Kimoto and Duthie-Holt, 2006). Larval galleries are typically perpendicular to the egg galleries.

Adults must feed in order to achieve sexual maturity. Maturation feeding usually occurs along the trunk but may also occur on the root collar or on branches (Kimoto and Duthie-Holt, 2006). These galleries are characterized by large quantities of frass. Mature beetles overwinter in forest litter whereas pupae, larvae and some adults overwinter under the bark of larch host trees (EPPO, 2005).

SYMPTOMS AND DAMAGE

Ips subelongatus is capable of attacking both apparently healthy trees and stressed trees but they most frequently occur on trees that have been stressed by other factors such as wildfire or other pests. Mature trees are preferred. It is often found in association with infestations of other bark beetles and wood-borers such as *Scolytus morawitzi*, *Xylotrechus altaicus, Monochamus galloprovincialis* and *Melanophila guttulata* (Orlinski, 2004).

Repeated attacks by this species can affect the growth and rate of timber production, occasionally leading to dieback or death of a host tree. Characteristic symptoms of attack by *I. subelongatus* include: sparse crowns of larch trees with partly dead tops and branches; wilting of needles; fading of foliage from green to yellow and finally to red; resin flow from entrance holes; the presence of small round exit holes, pitch tubes, reddish frass on the bark surface and a gallery system with central chamber and radial larval galleries under the bark (EPPO, 2005). As with other conifer bark beetle species, *Ips subelongatus* is a vector for blue-stain fungi (*Ophiostoma* spp.) which hastens the death of trees and discolours the wood resulting in loss of timber grade and value.


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Galleries created by Ips subelongatus

DISPERSAL AND INTRODUCTION PATHWAYS

Adult *Ips* beetles are capable of flying up to 4 km in search of suitable host material and they are also subject to wind dispersal. Transport of untreated larch wood can provide a means of introduction of immature stages and adults.

CONTROL MEASURES

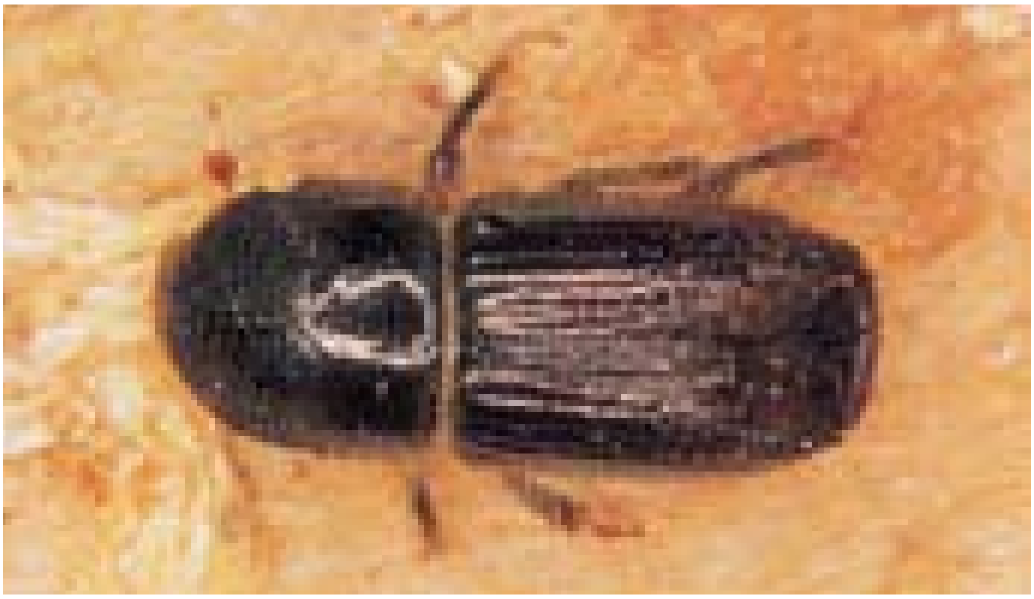
Control measures include silvicultural measures such as rapid removal and processing of infested trees, improving the resistance of forests, thinning, and treatments with chemical and biological preparations (EPPO, 2005). Biological control agents such as nematodes, microorganisms, parasitoids and predators may also play a role in regulating *I. subelongatus* populations. A forecasting system has been developed in China.

Since it is virtually absent from Europe with the exception of a small area in northeastern European Russia, *Ips subelongatus* was added to the EPPO A2 action list of pests recommended for regulation as quarantine pests in 2004. Recommended control measures include requiring imported *Larix* wood and bark to be from a pest-free area and debarking or kiln-drying wood and bark from infested areas. These requirements are also extended to the less important hosts of *Abies*, *Picea* and *Pinus* species.

Ips typographus

Other scientific names: *Dermestes typographus* Linnaeus, 1758; *Bostrichus octodentatus* Paykull, 1800; *Ips japonicus* Niijima, 1909; *Ips sexdentatus* Börner, 1776; *Tomicus typographus* Linnaeus, 1758
Order and Family: Coleoptera: Scolytidae
Common names: European spruce bark beetle; spruce beetle; spruce engraver beetle; eight-toothed spruce bark beetle

Ips typographus Linnaeus, 1758 is one of the most serious and destructive pests of spruce in its native range of Asia and Europe. It is common throughout the entire natural range of *Picea abies* in Europe and also occurs in plantations in Western Europe, outside the natural range of the host. Outbreaks have occurred in the Czech Republic, Germany, Italy, Norway, Poland, Slovakia and Sweden. This pest has caused excessive secondary damage in forests already damaged by other factors such as severe storms. *I. typographus* is a significant quarantine pest risk in North America where it has been intercepted at several locations.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Adult European spruce bark beetle, Ips typographus

DISTRIBUTION

Native: Europe; Asia and the Pacific (northern)
Introduced: No records to date

IDENTIFICATION

Larvae are small, legless and whitish in colour with orange heads and the pupae are waxy white and approximately 4 mm long (Humphreys and Allen, 1999).

Adult beetles are cylindrical, reddish, dark brown or black in colour and approximately 4.2 to 5.5 mm long (EPPO/CABI, 1997; Kimoto and Duthie-Holt, 2006).

Long yellowish hairs cover the front of the head and the sides of the body. Both sexes have four spines on each side of the posterior portion of the forewings, with the third spine being the largest and enlarged at the tip (Kimoto and Duthie-Holt, 2006).

HOSTS

Picea spp., including *P. abies* (main host in Europe), *P. orientalis* and *P. yezoensis* (northern Asia); *Pinus* spp.; *Abies* spp.

BIOLOGY

The European spruce bark beetle attacks both stressed and healthy trees in groups and overwhelms the defence mechanisms of host trees. During non-outbreak periods, the beetles breed in wind-felled trees, slash and logs while during outbreaks the beetles kill healthy trees (EPPO/CABI, 1997). Attacks are initiated by the males, who construct nuptial chambers under the bark, emit aggregation pheromones and are subsequently joined by 1 to 4 females (Kimoto and Duthie-Holt, 2006). The females construct egg galleries in the inner bark where they lay approximately 50 eggs on each side. Young larvae feed in larval galleries which radiate at right angles to the egg gallery and become wider as the larvae grow. Pupation takes place at the ends of the larval galleries. Young adult beetles maturation feed under the bark creating characteristic tunnels in the wood before emerging through round exit holes approximately 2 to 3 mm in diameter (Humphreys and Allen, 1999). The beetles generally overwinter in the adult stage, mainly in the forest litter near the tree where they developed but also under the bark of the host tree.

The number of generations per year and the timing of the life cycle depend on climate. At high altitude and latitude only one annual generation is produced while in the lowlands of Central Europe two generations are typical and even three generations per year at warmer sites (EPPO/CABI, 1997). Spring flight occurs when the air temperature rises to approximately 20 °C which generally occurs from April to June in different parts of its range. The flight for the second generation generally takes place in July or August but in northern areas, adults emerge from July to October and in central Europe emergence of the second generation may take place as late as November (EPPO/CABI, 1997).

SYMPTOMS AND DAMAGE

The needles of attacked conifers turn yellow-green to reddish-brown and eventually drop within a few weeks. Other signs of infestation include red-brown frass in bark crevices, the presence of round exit holes, and small pitch tubes extruding from the bark (Kimoto and Duthie-Holt, 2006). Woodpecker damage may also be evident.

As with other conifer bark beetle species, *Ips typographus* is a vector for blue-stain fungi (*Ophiostoma* spp., *Ceratocystis polonica*) which hastens the death of trees, discolours the wood and can result in loss of timber grade and value.

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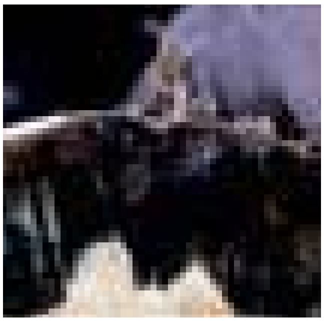

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Extensive gallery systems, blue-stained wood and round exit holes indicate attack by Ips typographus

DISPERSAL AND INTRODUCTION PATHWAYS

Adult *Ips* beetles are capable of flying up to 4 km in search of suitable host material and they are also subject to wind dispersal. Transport of unprocessed logs, wood products or wooden packing materials, dunnage or pallets containing bark strips can provide a means of introduction of immature stages and adults.

CONTROL MEASURES

The most effective control measure against damage by *Ips typographus* is to remove infested trees and all potential breeding materials such as weakened trees, windthrows and logs with bark before the new generation of adult beetles emerge. Silvicultural techniques aimed at increasing the stability and vitality of forest stands is also recommended. The use of pheromone-baited traps or trap trees has also been successfully used to trap and suppress beetle populations and prevent outbreak conditions.

As this pest is of major quarantine importance, debarking of logs before export is the best and likely only efficient way to prevent it from being introduced into new areas.

G. ALLARD

Pheromone traps have been used to help control Ips typographus *in Slovakia*

Leptocybe invasa

Order and Family: Hymenoptera: Eulophidae
Common names: blue gum chalcid

The blue gum chalcid, *Leptocybe invasa* Fisher & LaSalle, 2004, is a newly described insect that is a major pest of young eucalypt trees and seedlings. Believed native to Australia, it is currently spreading through Africa, Asia and the Pacific, Europe and the Near East. Information on the taxonomy, distribution, biology and economic impacts of the blue gum chalcid are still being investigated.

Z. MENDEL

Adult female Leptocybe invasa

DISTRIBUTION

Native: believed native to Australia (Asia and the Pacific) although its distribution there is still unknown.

Introduced: Africa: Algeria, Kenya (2002), Morocco, South Africa (2007), the United Republic of Tanzania (2005), Uganda (2002)

Asia and the Pacific: India, New Zealand, Thailand, Viet Nam

Europe: France, Italy, Portugal, Spain, Turkey

Near East: Islamic Republic of Iran, Israel, Jordan, the Syrian Arab Republic

IDENTIFICATION

The female chalcid is a small wasp, brown in colour with a slight to distinctive blue to green metallic shine (TPCP, 2005). The average length is 1.2 mm. With the exception of one record describing males in Turkey, only females of this species, which reproduce by parthenogenesis, have been observed (EPPO, 2008). Larvae are minute, white and legless.

HOSTS

The blue gum chalcid has a relatively narrow host range attacking eucalypt species (Mendel *et al.*, 2004). Suitable host species include *Eucalyptus saligna*, *E. grandis*, *E. deanei*, *E. globulus ssp. globulus*, *E. nitens*, *E. botryoides*, *E. camaldulensis*, *E. gunnii*, *E. robusta*, *E. bridgesiana*, *E. viminalis* and *E. tereticornis*.

BIOLOGY

Attacks take place within 1 to 2 weeks of bud break. Eggs are laid in the epidermis of the upper sides of newly developed leaves, on both sides of the midrib, in the petioles and in the parenchyma of twigs (TPCP, 2005; EPPO, 2008). White minute, legless larvae develop within the host plant. Five stages of gall development have been recorded on *E. camaldulensis* in Israel (TPCP, 2005).

- The first symptoms of cork tissue appearing at the egg insertion spot begin one to two weeks after oviposition. A small change in the morphology of the attacked tissue is evident, the cork scar becomes bigger and the section of the midrib that carries the eggs often changes colour from green to pink.
- The typical bump shape of the galls develops and they reach their maximum size of about 2.7 mm wide.
- The green surface colour fades and tends to become pink while retaining its typical gloss.
- Glossiness of the gall surface is lost and its colour changes to light or dark red depending on whether the galls are present on leaves or stems.
- The galls change colour to light brown on leaves and red on stems. Emergence holes of the adult wasps are evident.

Two to three overlapping generations per year have been observed in the Islamic Republic of Iran, Israel and Turkey (Mendel *et al.*, 2004).

Z. MENDEL

Ovipositing female Leptocybe invasa

SYMPTOMS AND DAMAGE

The developing larvae form bump-shaped galls on the leaf midribs, petioles and stems of new growth of young eucalypt trees, coppice and nursery seedlings. Severely attacked trees show leaf fall, gnarled appearance, loss of growth and vigour, stunted growth, lodging, dieback and eventually tree death (Mendel *et al*., 2004).

During outbreaks wasp pressure is quite intensive and all new growth may be damaged. While the impact of the wasp on mature tree development is not yet clear, galls can be found on most leaves if the wasp occurs in large numbers (TPCP, 2005).

G. ALLARD

G. ALLARD

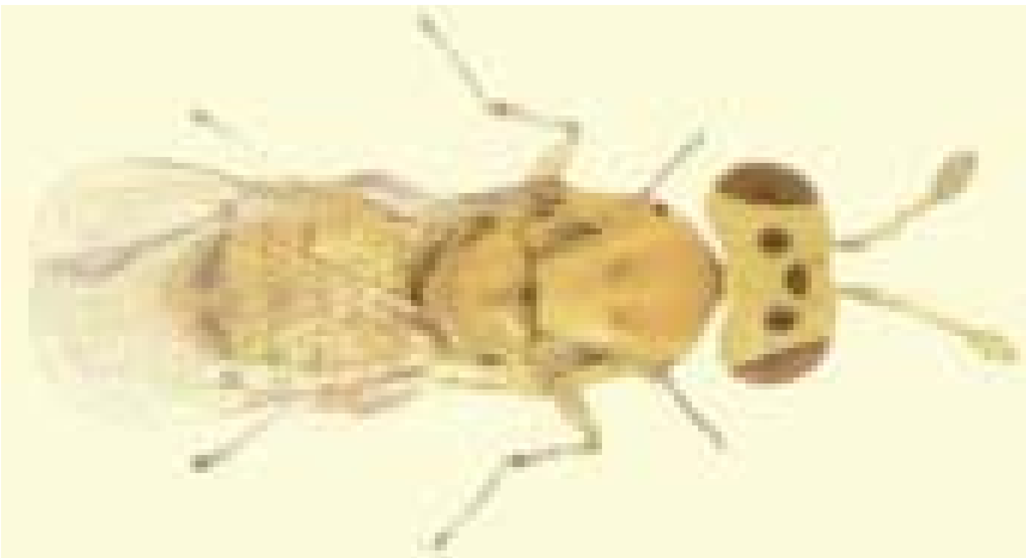
Damage caused by Leptocybe invasa *on eucalypt branches and leaf petioles, Kibaha, the United Republic of Tanzania. Left: young galls; right: older galls with exit holes*

DISPERSAL AND INTRODUCTION PATHWAYS

Possible pathways of introduction include movement of nursery stock. The adult wasps are very small and are thus incapable of long distance flight.

CONTROL MEASURES

There are currently no control measures for *Leptocybe invasa* although research on possible biological control agents is ongoing in Australia and Israel.



Z. MENDEL

Aprostocetus sp., *a natural enemy of* Leptocybe invasa, *recently released in Israel*

Lymantria dispar

Other scientific names: *Porthetria dispar* Linnaeus; *Ocneria dispar* Linnaeus; *Bombyx dispar* Linnaeus; *Hypogymna dispar* Linnaeus; *Liparis dispar* Linnaeus; *Phalaena dispar* Linnaeus; *Porthesia dispar* Linnaeus
Order and Family: Lepidoptera: Lymantriidae
Common names: gypsy moth; Asian gypsy moth; European gypsy moth

The gypsy moth, *Lymantria dispar* Linnaeus, 1758, is a significant defoliator of a wide range of broadleaf and even conifer trees. While low population levels can exist for many years without causing significant damage, severe outbreaks can occur resulting in severe defoliation, growth loss, dieback and sometimes tree mortality. Two strains of gypsy moth exist: the Asian strain, of which the female is capable of flight; and the European strain, of which the female is flightless. This moth is considered a significant pest in both its native and introduced ranges.


G. ALLARD

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Gypsy moth egg masses, larva and adults

DISTRIBUTION

Native: The Asian strain is native to southern Europe, northern Africa, Asia and the Pacific (central and southern, and Japan).
The European strain is found in temperate forests throughout Western Europe.
Introduced: The European strain has been introduced to North America, in Canada (1912 first detected, 1924 first infestation) and the United States (1869).
The Asian strain has been introduced into Europe (Germany, other countries in the region) where it readily hybridizes with the European strain. A breeding colony was reported in 1995 in Europe (United Kingdom) but there was no establishment. This strain has been introduced but has not established in North America (Canada, United States) (Wallner, 2000a).

IDENTIFICATION

The Asian gypsy moth is virtually identical in appearance to its European counterpart (Wallner, 2000a). Adult females are white or cream in colour and are much larger than the males with a wingspan of 55 to 70 mm (Wallner, 2000a; Kimoto and Duthie-Holt, 2006). Adult males are mottled brown in colour and have a wingspan of 35 to 40 mm (Wallner, 2000a; Kimoto and Duthie-Holt, 2006). Both sexes have a dark, crescent-shaped mark on the forewing and pectinate antennae, although the longer branches on the males give their antennae a feathered appearance (Kimoto and Duthie-Holt, 2006).

Egg masses are ovoid, 3 to 6 cm in length and 2 to 3 cm in width, and can contain 100 to 1 000 eggs (Wallner, 2000a). They are covered in tan coloured hairs from the female's abdomen and eventually become sun bleached with age (Brandt, 1994; Kimoto and Duthie-Holt, 2006). Spent egg masses have small pin-sized holes created by emerging larvae.

Newly hatched larvae are 3 mm in length and tan in colour but turn black within 24 hours (Wallner, 2000a). The first and third instars are black with long hairs while the second instar is brown with short hairs (Kimoto and Duthie-Holt, 2006). The fourth, fifth and sixth instars are quite similar to each other and may be light to dark gray with flecks of yellow. They have long dark or golden hairs and two rows of tubercles along the back which are typically arranged in five pairs of blue tubercles followed by six pairs of red, but variations are known to occur (Kimoto and Duthie-Holt, 2006). Mature larvae are approximately 50 to 90 mm in length (Wallner, 2000a).

HOSTS

Both strains have exceptionally wide host ranges, more than 250 species, although the Asian strain is even broader than the European strain. Preferred hosts of both forms include *Quercus*, *Populus*, *Salix*, *Tilia*, *Betula* and *Malus* species. *Larix*, *Ulmus* and *Diospyros* species are also highly preferred. Conifers growing in mixture with preferred hosts can also be defoliated during periods of high insect pest densities (Wallner, 2000a).

BIOLOGY

Both the Asian and European strains of the gypsy moth have one generation per year. Adults are active in July and August when mating and egg-laying occur (Wallner, 2000a). Adult females of Asian strains are capable of flight whereas females of European strains are flightless. Females lay egg masses indiscriminately on almost any surface including tree bark, branches, rock piles, lawn furniture, birdhouses, wood piles, logs, recreational vehicles and equipment.

Larvae hatch in early May and climb to the tree tops and balloon on silken threads to neighboring trees where they feed gregariously (Wallner, 2000a). Male gypsy moth larvae typically pass through five instars while females have six instars (Wallner, 2000a). Early instar larvae excavate small holes in leaves and as the larvae grow they make larger holes and consume the leaf margins; final instar larvae consume the entire leaf (Kimoto and Duthie-Holt, 2006). They are primarily nocturnal feeders and rest in protected locations such as bark flaps, holes and wounds on host trees during the day.

Pupation takes place in sheltered places; pupae may be found attached by silken thread to branches, tree trunks, rocks, forest debris, buildings or fences (Kimoto and Duthie-Holt, 2006). Adults emerge approximately two weeks later.

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G. ALLARD

Defoliation of trees by the gypsy moth in Romania (L) and Kyrgyzstan (R)

SYMPTOMS AND DAMAGE

Populations of the gypsy moth can occur at low levels in forests for many years without causing significant damage. However, at times there are significant outbreaks, frequently coinciding with periods when the trees are under stress such as in Central Europe in the 1990s. These outbreaks cause severe defoliation of host trees resulting in growth loss, dieback and sometimes tree mortality. Tree mortality often occurs when there are several sequential outbreaks. Outbreaks typically last for about three years and collapse when host trees are weakened to the point that they produce little or no foliage for the larvae to feed upon in the following spring. High levels of parasitism can also cause outbreaks to collapse.

DISPERSAL AND INTRODUCTION PATHWAYS

Adults of Asian strains are capable of flight and thus have strong dispersal ability whereas females of European strains are flightless. Young larvae can move some distance by ballooning from the tops of trees.

Pathways of introduction of the gypsy moth include movement of vehicles, camping equipment, nursery stock, ships, and equipment that has been exposed for a period to the outdoors. Ecotourism may contribute to ignorant or passive possession and dispersal and thus awareness campaigns are important.

CONTROL MEASURES

Preventative measures include thinning of forest stands to improve tree vigour and thinning to reduce the proportion of preferred host trees. Small infestations of gypsy moths particularly on ornamental trees can be controlled by collecting and destroying the egg masses before the eggs hatch (Brandt, 1994). Mass-trapping through the use of pheromones can also assist with control.

BUGWOOD.ORG/J.H. GHENT/2122004

Aerial spraying operations using Bacillus thuringiensis *var* kurstaki *(Btk) (Foray 76B) for gypsy moth control, United States*

Aerial and ground application of biological insecticides is the most common method for eradicating new isolated populations and also to suppress outbreaks of well established populations. The most common biological insecticide used against the gypsy moth is *Bacillus thuringiensis* (Bt) which disrupts the digestive system of larvae, suppressing their appetites and eventually resulting in death typically within 7 to 10 days. In the United States the gypsy moth is considered the most costly of introduced forest insect pests with annual control expenditures exceeding US$ 35 million since 1980 (Wallner, 2000a).

A number of natural predators have been used to control *L. dispar*. Vertebrate predators are important in maintaining low densities, parasites are often abundant during outbreaks, and diseases, especially a nucleopolyhedrosis virus, have been noted to be responsible for the collapse of outbreak populations (Wallner, 2000a). Another important natural control is the fungal pathogen, *Entomophaga maimaiga*, which is not dependent on gypsy moth density (Wallner, 2000a).

Predictive models have been used to determine risk assessment and potential damage in new areas.

Lymantria monacha

Other scientific names: *Psilura monacha* Linnaeus; *Liparis monacha* Linnaeus; *Ocneria monacha* Linnaeus; *Phalaena monacha* Linnaeus; *Porthetria monacha* Linnaeus; *Bombyx monacha* Linnaeus, 1758; *Noctua heteroclita* Müller, 1764; *Bombyx eremita* Hübner, 1808; *Bombyx nigra* Freyer, 1833; *Liparis monacha* var. *oethiops* De Selys-Longchamps, 1857; *Psilura transiens* Thierry Mieg, 1886; *Lymantria transiens* Lambillion, 1909; *Lymantria monacha flaviventer* Kruilikovsky; *Lymantria monacha gracilis* Kruilikovsky; *Lymantria fasciata* Hannemann, 1916; *Lymantria kusnezovi* Kulossow, 1928; *Lymantria brunnea* Stipan, 1933; *Lymantria monacha chosenibia* Bryk; *Lymantria monacha matuta* Bryk; *Lymantria monacha idae* Bryk; *Lymantria monacha lateralis* Bryk; *Lymantria monacha eremita*; *Lymantria monacha nigra*
Order and Family: Lepidoptera: Lymantriidae
Common names: nun moth; tussock moth; black arches moth; black-arched tussock moth

Lymantria monacha Linnaeus, 1758 is a major pest of broadleaved and coniferous trees in Europe and Asia. Defoliation by nun moth larvae can kill host trees especially conifers and has caused extensive losses despite intervention with biological and chemical insecticides. In parts of Europe, the occurrence of outbreaks has increased possibly as a result of the establishment of extensive pine plantations in poor quality areas. A serious outbreak was recorded in Europe between 1978 and 1985 and again in 1992 in Poland which involved hundreds of thousands of hectares.

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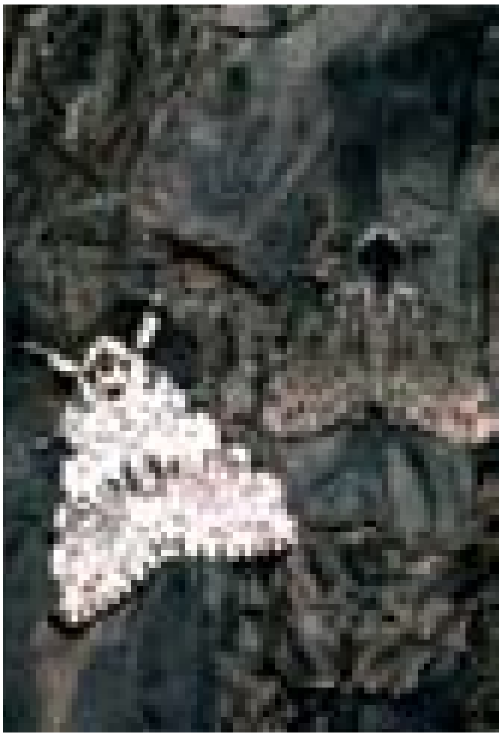

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Lymantria monacha *larva and adults (female and male)*

DISTRIBUTION

Native: Asia and the Pacific; Europe
Introduced: No records to date

IDENTIFICATION

Adult nun moths are moderately sized, hairy and often stout-bodied. Their forewings are white with numerous black, transverse, wavy lines and patches and the hind wings are greyish, with dark patches along the outer edge (Humphreys and Allen, 2002). Black and grey-brown forms occasionally occur. Females have a reddish-brown abdomen with black bands, short saw-like antennae, an extremely long extensible ovipositor and a wingspan of 45 to 55 mm (Humphreys and Allen, 2002; Kimoto and Duthie-Holt, 2006). Males have a grey-black abdomen, feathery antennae and a wingspan of 35 to 45 mm (Wallner, 2000b; Kimoto and Duthie-Holt, 2006).

Pupae are stout, shiny reddish-brown with light-coloured hair, and approximately 18 to 25 mm in length (Humphreys and Allen, 2002).

Newly hatched larvae are approximately 4 mm long and tan in colour though they turn black within 24 hours (Wallner, 2000b). Mature larvae are 30 to 40 mm long, light to dark brown with an orange to pale-brown head with black markings (Wallner, 2000b; Kimoto and Duthie-Holt, 2006). The first four abdominal segments have a dorsal pair of small, bluish glandular protrusions, the sixth and seventh segments have prominent mid-dorsal, orange glandular warts, and a dark dorsal band runs from the second to the eleventh segment (Kimoto and Duthie-Holt, 2006). Numerous short black and white hairs are present; hairs on the prothoracic and anal segments are longer.

Eggs are round, slightly concave in the centre, one millimetre in diameter, and initially orange-brown or purple in colour, turning dark brown over time (Kimoto and Duthie-Holt, 2006). They are laid in masses in bark crevasses of host trees and cannot be seen unless the outer bark is peeled away (Wallner, 2000b).

HOSTS

Species of *Pinus, Picea, Larix* and *Abies* are preferred hosts but the nun moth will also feed on many broadleaf trees including *Acer, Betula*, *Carpinus*, *Fagus*, *Fraxinus*, *Malus*, *Prunus*, *Quercus* and *Ulmus* species and other fruit trees. Host tree preference varies between areas.

BIOLOGY

Nun moth has one generation per year. Both male and female adults are strong fliers and are active for 3 to 5 weeks between July and September when they mate and deposit eggs (Wallner, 2000b). Females lay masses of 70 to 300 eggs, typically in bark crevices. However they will also lay on any hard surface such as motor vehicles. They overwinter as eggs and hatch in spring. Newly hatched larvae feed on young foliage, often towards the top of trees, while older larvae feed on older foliage. Larvae develop through five to seven instars depending on host type and health, weather and other factors (Wallner, 2000b). Pupation usually occurs in July on the tree trunks, but when populations are high, pupae can also be found high in tree crowns. Adults emerge in mid-summer; females live approximately 10 days while males may live up to 24 days after emerging (Wallner, 2000b).

SYMPTOMS AND DAMAGE

Nun moth larvae feed on needles or leaves and can severely defoliate host trees resulting in tree mortality. They tend to attack monoculture stands of trees that are growing in poor conditions. The nun moth can decimate vast areas of forest and increase the risk of attack by other insects such as bark beetles. Outbreaks last for approximately five years in pine forests and seven years in spruce forests (Humphreys and Allen, 2002).

*Heavy defoliation of Norway spruce (*Picea abies*) stands in the Czech Republic by the nun moth*

On conifer host trees, young larvae feed on the foliage of newly expanded shoots whereas older larvae are able to feed on more mature foliage but still prefer new needles. They can be wasteful feeders, eating only the base of a needle which results in partially uneaten needles falling to the ground. Defoliated trees exhibit thinned crowns and are reddish-brown in colour (Kimoto and Duthie-Holt, 2006). During outbreaks, over 50 percent of the foliage can be defoliated and successive years of severe defoliation can cause tree mortality (Kimoto and Duthie-Holt, 2006). On broadleaved host trees, larval feeding initially creates holes in the leaves. As feeding progresses, however, entire leaves are consumed except for the middle vein (Kimoto and Duthie-Holt, 2006).

DISPERSAL AND INTRODUCTION PATHWAYS

Adults are strong fliers and can spread fair distances, males have been known to disperse up to 3.5 km, and young larvae can balloon from tree tops. Eggs may also be transported on logs, ships or vehicles. Since egg masses are typically deposited in bark crevices of host trees, long distance transport of this species could be facilitated by the movement of unprocessed logs and crates, pallets or dunnage containing large strips of bark.

CONTROL MEASURES

Nun moth has a number of natural enemies including parasitoids, predators and disease (Wallner, 2000b). Birds have been known to help control egg and larval stages and a baculovirus has also been implicated in population collapses and has been cultured and applied for control (Wallner, 2000b).

Pheromone trapping can be used both for detection purposes and as a means of disrupting mating (Humphreys and Allen, 2002). Direct control with biological insecticides, such as *Bacillus thuringiensis*, can be effective over large areas.

Orthotomicus erosus

Other scientific names: *Bostrichus duplicatus* Ferrari; *Bostrichus laricis* Perris; *Ips erosus* Wollaston; *Ips erosus* var. *robustus* Knotek; *Tomicus erosus* Wollaston; *Tomicus rectangulus* Eichoff
Order and Family: Coleoptera: Scolytidae
Common names: Mediterranean pine engraver beetle; European bark beetle; Mediterranean pine beetle

Orthotomicus erosus Wollaston, 1857 is a bark beetle that can kill pines particularly those planted at low elevations and on dry sites. It is usually considered a secondary pest infesting fallen and stressed trees and is often found in association with other forest pests. Its successful introduction into countries outside its native range has lead to some concern, particularly in regions with significant areas of pine plantations.

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Adult Mediterranean pine engraver beetle, Orthotomicus erosus

DISTRIBUTION

Native: Northern Africa (Morocco); Asia and the Pacific; Europe
Introduced: Africa: South Africa, Swaziland (early 1980s)
Asia and the Pacific: Fiji
Europe: Finland, Sweden, United Kingdom
Latin America and the Caribbean: Chile (1986 not now detected)
Near East: Tajikistan
North America: United States (2004)

IDENTIFICATION

Adult beetles averages 2.7 to 3.8 mm length and are reddish-brown in colour (Cavey, Passoa and Kucera, 1994; Eglitis, 2000). The head is covered by a thoracic shield and is not visible when viewed dorsally. The posterior portion of the forewings is concave with four lateral spines; the second spine is the broadest and most conspicuous (Eglitis, 2000).

Larvae are white or cream-coloured, legless grubs with amber heads and are approximately 5 mm long when mature (Eglitis, 2000).

HOSTS

Orthotomicus erosus primarily attacks pine species such as *Pinus armandii*, *P. brutia*, *P. brutia* var. *eldarica*, *P. brutia* var. *pityusa*, *P. canariensis*, *P. caribaea*, *P. coulteri*, *P. echinata*, *P. kesiya*, *P. massoniana*, *P. mugo* subsp. *uncinata*, *P. nigra*, *P. nigra* ssp. *pallasiana*, *P. patula*, *P. pinaster*, *P. pinea*, *P. radiata*, *P. strobus*, *P. sylvestris*, *P. tabulaeformis* and *P. yunnanensis*. It will attack other conifer species such as *Pseudotsuga menziesii* and *Picea*, *Abies* and *Cedrus* species but it is believed to breed only in pines.

BIOLOGY

The Mediterranean pine engraver typically attacks recently fallen or cut pine trees and branches, but it can colonize and kill standing trees especially those stressed by drought, fire or wind (Haack, 2004). They generally breed in the rough-barked sections of the main trunk and in branches larger than 5 cm in diameter (Eglitis, 2000). Smooth-barked portions of host trees are primarily used for maturation feeding.

Attacks are initiated by males that bore through the bark to the phloem-cambium layer where they construct a nuptial chamber. They emit aggregation pheromones and are soon joined by one to three females, each of which mates with the male and then constructs an individual egg gallery from the nuptial chamber, parallel to the grain of the wood (Eglitis, 2000). Females typically lay 26 to 75 eggs in niches along the sides of the galleries (Eglitis, 2000; Lee, Smith and Seybold, 2005). The eggs hatch and the larvae feed in the phloem causing a distinctive engraving pattern; they develop through three instars expanding the tunnels as they feed (Lee, Smith and Seybold, 2005). When the larvae are ready to pupate, they tunnel towards the bark particularly if the phloem of the host tree is thick (Lee, Smith and Seybold, 2005).

Adult beetles maturation feed beneath the bark of the brood host or in another suitable host tree, sometimes of a different species (Eglitis, 2000; Haack, 2004). Between mid-October and December, they aggregate under the bark of host trees to overwinter. Small round exit holes measuring approximately 1.5 mm in diameter are apparent in the outer bark of host trees after adults emerge (Lee, Smith and Seybold, 2005). Adult beetle flight can occur through a broad temperature range of 14 to 38 °C; in Israel, the threshold for flight is even lower during winter (12 °C) (Eglitis, 2000).

The Mediterranean pine engraver completes two to seven generations per year in different parts of its range, depending on local temperatures and host quality (Haack, 2004). Two generations per year are typical in Turkey, France and Morocco, three to four generations are observed in Tunisia and South Africa, and three to five in Israel (Lee, Smith and Seybold, 2005).

SYMPTOMS AND DAMAGE

The Mediterranean pine engraver is usually a secondary bark beetle that infests recently fallen trees, broken branches, slash, and standing trees that have been wounded or are stressed from a variety of factors such as fire or drought (Eglitis, 2000; Lee, Smith and Seybold, 2005). Attacks on stressed trees frequently leads to death of the tree.

The most conspicuous indication of attack by *Orthotomicus erosus* is the fading of foliage of infested host trees from green to yellow to reddish brown (Eglitis, 2000). Small entrance holes with frass pushed out and exit holes may be visible on the bark surface, especially on smoother bark surfaces; entrance and exit holes may be difficult to detect on rough-barked regions of the tree (Lee, Smith and Seybold, 2005). If vigorous trees are attacked, pitch tubes may be found in the bark crevices (Eglitis, 2000). Inspection of the underside of the bark of declining pines may reveal a dense network of galleries (Lee, Smith and Seybold, 2005). These galleries typically consist of a nuptial chamber and one to five longitudinal egg galleries but may vary depending on host type and location (Eglitis, 2000).


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Galleries created by the Mediterranean pine engraver beetle

This beetle is often found in association with other forest pests including *Carphoborus minimus*, *Hylastes angustatus*, *Hylurgus ligniperda*, *Matsucoccus feytaudi*, *Pityogenes calcaratus*, *Pissodes nemorensis*, *Tomicus destruens* and *T. minor* (Eglitis, 2000). As with other conifer bark beetle species, *Orthotomicus erosus* is a vector for a number of wood-staining or blue-stain fungi which hastens the death of trees, discolours the wood and can result in loss of timber grade and value.

DISPERSAL AND INTRODUCTION PATHWAYS

Adult beetles are capable of flying considerable distances in search of suitable hosts and are also subject to wind dispersal (Eglitis, 2000). All life stages of the Mediterranean pine engraver can be easily transported on wood packing materials, particularly those made from pine and containing bark strips. Prior to the implementation of ISPM No. 15, this pest was commonly intercepted on wood packing materials such as crates and pallets since it often attacks recently cut trees which are typically converted into such materials (Haack, 2004).

CONTROL MEASURES

Preventative measures that involve good sanitation, limiting movement of recently cut pine branches and stems, keeping standing trees healthy and vigourous and early detection of infestations are the best defence against the Mediterranean pine engraver (Lee, Smith and Seybold, 2005). Proper care and watering of standing trees can reduce the probability of an outbreak since these beetles are known to primarily attack living trees under stress. It is recommended that managers avoid piling any pine material next to live trees and that they chip, burn or debark freshly cut pine material or for small quantities of pine material, completely cover them with thick, clear plastic sheeting in a sunny location (Lee, Smith and Seybold, 2005).

Pinus brutia *killed by the Mediterranean pine engraver beetle, Cyprus*

The Mediterranean pine engraver has several known natural enemies. The Syrian woodpecker (*Picoides syriacus*) has been observed feeding on the beetle in Israel (Lee, Smith and Seybold, 2005). In South Africa, the larvae are parasitized by wasps, such as *Dendrosoter caenopachoides* and *Metacolus unifasciatus*, and eaten by several predatory beetles including *Alulonium ruficorne*, *Corticeus pini* and *Platysoma oblongum* and the predatory bug *Lyctoris* sp. (Lee, Smith and Seybold, 2005). A parasitoid, *Dendrosoter caenopachoides*, was reared and released in South Africa and it has since established (Eglitis, 2000).

Phoracantha recurva and *Phoracantha semipunctata*

Phoracantha recurva **Newman, 1840**
Order and Family: Coleoptera: Cerambycidae
Common names: eucalyptus longhorned borer; eucalyptus borer; longicorn beetle; yellow phoracantha borer; yellow longicorn beetle

Phoracantha semipunctata **Fabricius, 1775**
Order and Family: Coleoptera: Cerambycidae
Common names: eucalyptus longhorned borer; common eucalypt longhorn; common eucalypt longicorn; eucalypt longhorn; eucalyptus borer; longicorn beetle; blue gum borer; firewood beetle

Phoracantha recurva and *Phoracantha semipunctata* are both serious borer pests of eucalypts, particularly those planted outside their natural range. In their native Australia they are considered minor pests attacking damaged, stressed or newly felled trees but they have become established in many temperate and tropical regions worldwide where they have been known to kill even healthy trees.

Phoracantha recurva *(L) and* Phoracantha semipunctata *(R)*

DISTRIBUTION

Phoracantha recurva
Native: Asia and the Pacific: Australia
Introduced: Africa: Malawi, Morocco, South Africa, Tunisia (1999), Zambia
Asia and the Pacific: New Zealand, Papua New Guinea
Europe: Greece (one record), Spain (1998)
Latin America and the Caribbean: Argentina (1997), Brazil (2001), Chile (1997), Uruguay (1998)
North America: United States (1995)
Phoracantha semipunctata
Native: Australia

Introduced: Africa: Algeria (1972), Egypt (1950s), Libyan Arab Jamahiriya (1998), Morocco (1962), Tunisia (1962)
Europe: Canary Islands (1991), France (1984), Italy (around 1969), Netherlands (detected but believed eradicated), Portugal (1980), Spain (1980), Turkey (1959)
Latin America and the Caribbean: Brazil (1994)
Near East: Cyprus (around 1967), Israel (1940s), Lebanon (1950s)
North America: United States (California, 1980s)

IDENTIFICATION

Adult eucalyptus longhorned borers are approximately 14 to 30 mm long and have shiny, dark brown and yellow to cream-coloured areas on their wing covers (University of California, 2000). Antennae are as long as or longer than the body and the antennae of males have prominent spines.

Adults of both species are very similar to one another although there are differences in wing cover colour and hairs and spines on antennae (University of California, 2000). *Phoracantha semipunctata* has wing covers that are mostly dark brown with a zigzag line bisecting the cream-coloured area in the middle whereas the wing covers of *P. recurva* are mostly cream to yellowish in colour with dark brown areas primarily limited to the posterior end. Long, dense golden hairs can be found on the underside of each antenna segment on *Phoracantha recurva*; such hairs are either absent or sparse on *P. semipunctata*.

Mature larvae are cream-coloured, legless and may be more than an inch in length (University of California, 2000). Eggs are ovoid and pale yellow in colour.

HOSTS

Eucalyptus species

BIOLOGY

Female beetles are attracted to stressed trees or freshly cut wood where they lay eggs in groups under loose bark. The larvae tunnel under the bark and into the cambium layer and effectively ring bark the host trees. The larval feeding can rapidly kill the trees or cause significant damage to the timber of affected trees. Larvae take 2 to 6 months to develop depending on the moisture conditions in the logs. Pupation takes place in pupal chambers. Adults live for several weeks.

SYMPTOMS AND DAMAGE

Phoracantha species tend to attack damaged or stressed trees; vigorous, well-watered trees are rarely attacked though it does occur.

The presence of holes in the bark and stains or oozing liquid on limbs or trunks are common symptoms of longhorned borer attack (University of California, 2000). Foliage may also discolour and wilt, and limbs may dieback.

The feeding by larvae and resulting galleries created within host trees can girdle trees killing them. Such trees are characterized by a thin canopy with wilted or dry leaves and cracked bark packed with frass (University of California, 2000). Infested trees are often killed in a matter of a few weeks and resprouting may occur from the tree base.

DISPERSAL AND INTRODUCTION PATHWAYS

Adults are moderately long-lived and are strong fliers that are thus capable of naturally dispersing a fair distance. Dispersal over greater distances occurs through movement of nursery stock and freshly cut wood with high moisture content. Introduction into southern Africa is believed to have been through the importation of infested railway sleepers.

CONTROL MEASURES

The same management and control methods are applied to both *Phoracantha* species and are based on good cultural practices and biological control. Such practices involve reducing tree stress through irrigation and protection against injury, planting resistant or tolerant eucalypt species and avoiding activities that disrupt biological control (University of California, 2000).

Properly handling eucalyptus wood is also effective in controlling borer populations (University of California, 2000). Since moist wood is most suitable for ovipositing beetles, methods such as cutting and splitting wood to hasten the drying of the wood helps to reduce the length of time the wood can support beetle development. Bark can be removed from felled logs or the wood can be solarized by placing it in a sunny location for 10 to 12 weeks and covering it with ultraviolet-resistant plastic which prevents new beetles from attacking and resident beetles from emerging and spreading to standing hosts nearby. Infested eucalypt trees, branches and wood should be treated or destroyed by burying, burning or chipping.

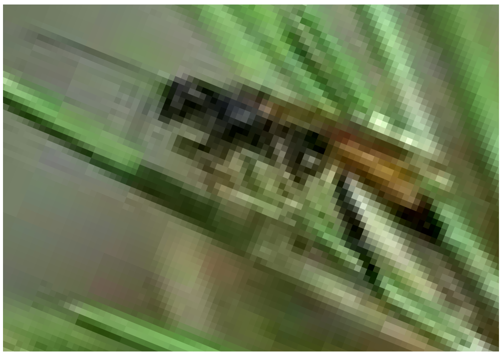
Chemical insecticides are not considered suitable or effective for the management of eucalyptus longhorned borer populations.

Biological control with natural enemies is possibly the best solution to controlling longhorned borer populations. At low beetle population levels, natural enemies may be better able to keep populations in check and vigorous trees can survive a few attacks. Some examples of biological control agents for *Phoracantha* species include the Australian parasitic wasps *Avetianella longoi*, *Callibracon limbatus*, *Jarra maculipennis*, *J. phoracantha* and *Syngaster lepidus*, and *Helcostizus rufiscutum* from California (University of California, 2000). Felled trap trees with bark are used to deliver the natural enemies and to attract gravid females.

Sirex noctilio

Other scientific names: *Sirex melanocerus* Thomson, 1871; *Paururus noctilio*
Order and Family: Hymenoptera: Siricidae
Common names: European woodwasp; sirex; sirex woodwasp; steel-blue horntail

Sirex noctilio Fabricius, 1793 is a major global threat to forests and the forest sector causing considerable damage and costs for control. In 1900, this pest was reported from New Zealand which represented the first time it was recorded outside of its native range. Since then it has gradually spread around the globe – to Australia in the 1960s, Latin America and the Caribbean in the 1980s, Africa in the 1990s and North America in this decade.



Adult sirex woodwasps: male (L); female (R)

DISTRIBUTION

Native: Africa (northern: Algeria, Morocco, Tunisia); Asia and the Pacific, Europe
Introduced: Africa: South Africa (1994)
Asia and the Pacific: Australia (1961), New Zealand (1900), Tasmania (1952)
Latin America and the Caribbean: Argentina (1985), Brazil (1988), Chile (2001), Uruguay (1980)
North America: Canada (2005), United States (2004)

IDENTIFICATION

Eggs are cylindrical, creamy white and approximately 0.30 to 0.35 mm wide and 1.35 to 1.56 mm long (Ciesla, 2003b). Larvae are creamy white in colour, legless with a distinctive dark spine at the posterior end (TPCP, n.d.). Length varies but larvae can reach up to 30 mm in length.

Adult wasps are metallic blue-black in colour with two pairs of clear yellow membranous wings, black antennae and an upturned, spear-shaped spine or plate (cornus) at the end of the abdomen (TPCP, n.d.; Walker, 2006). They are large, robust insects ranging in size from 10 to 44 mm in length (Walker, 2006). Females are uniform in colour with a prominent robust ovipositor located beneath the cornus, orange legs and black feet (Haugen and Hoebeke, 2005; Walker, 2006). Smaller than the female, the male wasp has orange middle abdominal segments and orange legs except for the hind legs which are thickened and black (Haugen and Hoebeke, 2005; Walker, 2006).

HOSTS

Sirex noctilio has a wide host range and is primarily a pest of *Pinus* spp. such as *P. attenuata*, *P. banksiana*, *P. brutia*, *P. canariensis*, *P. caribaea*, *P. contorta*, *P. densiflora*, *P. echinata*, *P. elliottii*, *P. halepensis*, *P. jeffreyi*, *P. kesiya*, *P. muricata*, *P. nigra*, *P. nigra austriaca*, *P. nigra calabrica*, *P. palustris*, *P. patula*, *P. pinaster*, *P. pinea*, *P. ponderosae*, *P. radiata*, *P. resinosa*, *P. strobus*, *P. sylvestris* and *P. taeda* (Carnegie *et al*., 2006; USDA-APHIS, 2007). *Pinus radiata, P. taeda* and *P. patula* are particularly susceptible (Carnegie *et al*., 2006). Species of *Abies*, *Larix*, *Picea* and *Pseudotsuga*, particularly *Pseudotsuga menziesii*, have also been attacked (USDA-APHIS, 2007).

BIOLOGY

The sirex woodwasp attacks living pines and is particularly attracted to stressed or dying trees with low sap pressure. The adult female drills into the wood of trees using her ovipositor, depositing eggs (20 to 500) as well as toxic mucus and a fungus (*Amylostereum areolatum*) which effectively kill the host tree (Hurley, Slippers and Wingfield, 2007). The movement of water and sugars within the tree trunk is impeded by the mucus causing foliage to wilt and creating suitable conditions for the fungus (Matthews, 2005). *Amylostereum areolatum* relies on *S. noctilio* for dispersal and inoculation into trees and the wasp larvae rely on the fungus for wood breakdown and food (USDA-APHIS, 2007).

Unfertilized eggs develop into males whereas fertilized eggs produce females (Haugen and Hoebeke, 2005). Larvae can hatch as early as nine days after oviposition and can remain dormant for several months, particularly in cooler climates (Ciesla, 2003b). They feed in the wood, constructing large galleries and thus degrading wood quality. Once feeding is complete, the larvae enter prepupal and pupal stages; pupation lasts 16 to 21 days (Ciesla, 2003b). Adult wasps bore their way out of host trees leaving perfectly round exit holes. Males emerge before the females. The lifespan of adult woodwasps can be up to 12 days, but females that have deposited all their eggs may only live for three to four days (Ciesla, 2003b). Each generation takes between ten months and two years, the latter primarily in cooler climates.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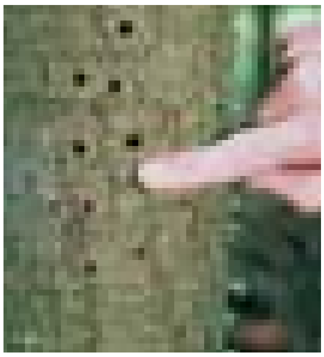
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Damage caused by Sirex noctilio

SYMPTOMS AND DAMAGE

Resin droplets and oviposition scars on the bark of trees are the first signs of infestation by sirex (Ciesla, 2003b). Tree crowns and foliage wilts and turns from green to yellow to reddish brown. Larvae tunnel in the wood creating galleries full of very fine frass, which significantly damages the wood. Round exit holes, approximately 3 to 8 mm in diameter, appear when the adult insects emerge.

DISPERSAL AND INTRODUCTION PATHWAYS

Sirex noctilio can spread naturally through flight and wind dispersal. Adults are strong fliers capable of traveling several kilometers in search of suitable host trees. For example, in southwestern South Africa the dispersal rate of *S. noctilio* has been estimated at 48 km per year and rates of 30 to 40 km per year have been observed in Australia (Carnegie *et al*., 2006). Other pathways of *S. noctilio* dispersal include movement of nursery stock, untreated pine logs and sawnwood, and untreated packing materials. The woodwasp is believed to have entered Argentina, Australia, New Zealand and South Africa in wooden packaging from Europe or North Africa (Keiran and Allen, 2004).

CONTROL MEASURES

The development of control strategies for *S. noctilio* originated in Australia and they are being used by various Southern Hemisphere countries where sirex has established. Control of this pest is achieved through a combination of silvicultural and biological measures including the restricted movement of infested materials, population monitoring through survey and trap trees, good silvicultural management practices, and the use of biological control agents (Carnegie, Eldridge and Waterson, 2005; USDA-APHIS, 2007). Since stressed trees are a prime target for sirex attack, silvicultural measures which maintain the health and vigour of trees and managing plantations optimally can significantly reduce the risk of sirex attack (Carnegie, Eldridge and Waterson, 2005).

A variety of biological control agents have been applied to target the sirex woodwasp. The most effective is the parasitic nematode, *Beddingia* (=*Deladenus*) *siricidicola*, which infects sirex larvae rendering adult female wasps sterile (Carnegie, Eldridge and Waterson, 2005; Haugen and Hoebeke, 2005). Infected females emerge and lay infertile eggs which are infected with nematodes in trees thereby assisting in the spread of the nematodes. Several parasitic wasps have also been introduced into Southern Hemisphere countries to help control sirex, including *Ibalia leucospoides*, *Megarhyssa nortoni*, *Rhyssa hoferi*, *R. persuasoria* and *Schlettererius cinctipes* (Carnegie, Eldridge and Waterson, 2005).

Thaumetopoea pityocampa

Other scientific names: *Bombyx pityocampa* Denis & Schiffermüller; *Cnethocampa pityocampa*; *Thaumetopoea wilkinsoni* Tams
Order and Family: Lepidoptera: Thaumetopoeidae
Common names: pine processionary caterpillar

Thaumetopoea pityocampa Denis & Schiffermüller, 1775 is considered the most destructive forest insect pest throughout the Mediterranean Basin. It is a tent-making caterpillar that feeds gregariously and defoliates various species of pine and cedar. Note the taxonomic status of this pest is under review. In Cyprus for example, *Thaumetopoea wilkinsoni* is the preferred scientific name though it is considered an eastern Mediterranean form (race) of *Thaumetopoea pityocampa.*


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Pine processionary caterpillars, Thaumetopoea pityocampa

DISTRIBUTION

Native: Africa (North), Europe (southern), Near East. This pest is found in almost all the countries around the Mediterranean Sea with the exception of Egypt and Libyan Arab Jamahiriya.
Introduced: No records to date

IDENTIFICATION

Eggs are laid in cylindrical egg masses that range in length from 4 to 5 cm and are covered in pale buff scales which conceal them and mimic the pine shoots (Dajoz, 2000).

The larvae develop through five instars, recognized by differences in head capsule size. First instar larvae have dull green bodies. After the second moult, the caterpillar assumes its definitive appearance and the paired reddish dorsal hair patches on each body segment are evident (EPPO/CABI, 1997). Typically, they are darker in colder areas varying from dull bluish-grey to black. Lateral hairs vary in colour from white to dark-yellow while dorsal hairs are yellow to dull orange. The average head width of the fifth instar caterpillar is 4.8 mm for males and 3.4 mm for females (EPPO/CABI, 1997). Mature larvae are about 40 mm in length with a black head capsule (EPPO/CABI, 1997).

Pupation takes place in oval, yellowish or white silken cocoons. Pupae are oval, approximately 20 mm in length, and pale brownish-yellow in colour that changes to dark reddish-brown (EPPO/CABI, 1997).

Adult female moths have a wing-span of 36 to 49 mm while males have a wing-span of 31 to 39 mm (EPPO/CABI, 1997). Both sexes have a hairy thorax, a stout abdomen and a tuft of large scales covering the last segments. Antennae are filiform in females and pectinate in males. Forewings are dull ashen-grey with darker veins, margins and three transverse bands. Hindwings are white, fringed with grey and have a characteristic dark spot in the anal region.

HOSTS

Pinus and *Cedrus* species are primary hosts; *Larix decidua* is occasionally attacked. The rate of survival of this insect pest varies depending upon which species of plant it feeds, i.e. it is higher for *Pinus sylvestris* and *P. nigra*.

BIOLOGY

The life cycle of the pine processionary caterpillar is typically annual but may extend over two years at high altitudes or in northern latitudes (EPPO/CABI, 1997). Daily average sunshine plays an important role in defining the northern limit of distribution. At northern latitudes and at higher altitudes, adults emerge earlier.

The day after emergence and mating, females oviposit on pines nearest to their pupation site although they can fly several kilometres in search of hosts thereby quickly increasing the extent of the outbreak (EPPO/CABI, 1997; Dajoz, 2000). Eggs are laid in masses containing 70 to 300 eggs typically near the tips of branches in the crown. The larvae hatch after 30 to 45 days and aggregate in colonies. There are five instars during which the larvae change location as host foliage is consumed (Dajoz, 2000). The larvae change colour at each moult and at the third instar urticating hair patches appear. They spin silken nests which are abandoned with each move until the fourth instar when the winter nest is built. The winter nest is a large silk bag up to 20 cm in length where the larvae spend the cold season (Dajoz, 2000).

Pupation processions occur at the end of the larval stage in late winter and early spring. A female is usually at the head of the procession which leads the colony in a file searching for a suitable site, typically a bright warm area near a host tree, to tunnel underground and pupate in the soil (EPPO/CABI, 1997; Dajoz, 2000). The processions occur at temperatures of 10 to 22 °C; at lower temperatures the colonies regroup and at higher temperatures they bury themselves wherever suitable soil conditions exist. The larvae burrow 5 to 20 cm below the ground where they weave a cocoon and pupate (Dajoz, 2000). The pupae enter diapause which breaks one month before adult emergence. The emergence period generally lasts less than one month for vigorous populations and approximately six weeks for weakened populations in regression (EPPO/CABI, 1997).

If environmental conditions are unfavourable, they can remain in the pupal stage for several years therefore resulting in moths from several generations emerging simultaneously when favourable conditions occur, causing severe outbreaks (Vega *et al*., 1999).

SYMPTOMS AND DAMAGE

Infestation by *Thaumetopoea pityocampa* can be detected by the presence of white silken nests and brown and yellowing needles of partially eaten twigs (EPPO/CABI, 1997). The caterpillars feed on the foliage of host trees during the cooler months of the year causing significant defoliation. Defoliation damage is extremely serious in young reforested areas and young plantations where it may lead to death of trees. Although mature trees are rarely killed by this species, reduced growth rates are observed resulting in significant production losses. Host trees become stressed which can make them more susceptible to other agents including attack by secondary pest species. This insect is regarded as a major pest of Mediterranean pine forests because it can contribute to increment losses of approximately 30 percent.

Thaumetopoea pityocampa larvae have urticating hairs that can cause skin irritation, conjunctivitis, respiratory congestions and asthma in humans. Contact with dead larvae, cocoons, nests and debris from infested pine forests can also cause dermatitis and other symptoms throughout the year. This significant problem not only affects recreational and residential areas but also impacts silvicultural operations and grazing in forests (EPPO/CABI, 1997).

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Damage caused by the pine processionary caterpillar to trees in Cyprus

DISPERSAL AND INTRODUCTION PATHWAYS

Adults are reasonably strong fliers and are thus capable of natural dispersal to new areas. Pupation processions may travel up to 37 m (EPPO/CABI, 1997). The movement of nursery stock and soil could transport *T. pityocampa* pupae.

CONTROL MEASURES

Control measures targeting the pine processionary caterpillar should be applied when the pest is at its most vulnerable and when its predators are not as active (Dajoz, 2000). The period between larval hatching and building of winter nests is the most effective. Chemical and biological control treatments are typically applied aerially and the most effective insecticide is *Bacillus thuringiensis.* For small outbreaks or when population density is low, mechanical control by cutting and burning winter nests is also recommended (EPPO/CABI, 1997). Pheromone traps are also used for detection, monitoring and mass trapping.

There are a number of predators, parasitoids and diseases which play a role in the biological control of *Thaumetopoea pityocampa*. Eggs are attacked by the wasp parasitoids *Anastatus bifasciatus*, *Baryscapus servadeii*, *Oencyrtus pityocampae*, *Tetrastichus servadei* and *Trichogramma* sp. and the orthopteran predators *Barbitiste fischeri* and *Ephippiger ephippiger* (EPPO/CABI, 1997; Schmidt, Mirchev and Tsankov, 1997). Pine processionary larvae are attacked by the dipteran parasitoids *Phryxe caudata*, *Compsilura concinnata* and *Ctenophora pavida*, the hymenopteran parasitoids *Erigorgus femorator* and *Meteorus versicolor*, and the dipteran predator

Xanthandrus comptus (EPPO/CABI, 1997; Dajoz, 2000). Birds are also known to feed on these caterpillars. Pupae are attacked by the dipteran parasitoids *Villa brunnea* and *V. quinquefasciata*, the wasp parasitoids *Coelichneumon rudis*, *Ichneumon rudis* and *Conomorium eremita*, and the fungus *Beauveria bassiana* (EPPO/CABI, 1997; Dajoz, 2000). The most important diseases of *T. pityocampa* are caused by the viruses *Borrelina* sp. and *Smithiavirus pityocampae*, the bacteria *Bacillus thuringiensis* and *Clostridium* sp., and the fungi *Aspergillus flavus*, *Beauveria bassiana*, *Cordyceps* sp., *Metarhizium anisopliae*, *Paecilomyces farinosus*, *P. fumoso-roseus* and *Scopulariopsis* sp. (EPPO/CABI, 1997).

To avoid the accidental introduction of this pest into new areas, nursery stock, plants and trees, particularly *Pinus* and *Cedrus* species, should be examined for the presence of egg masses, caterpillar colonies and pupae (EPPO/CABI, 1997).

Thaumetopoea processionea

Other scientific names: *Bombyx pityocampa* Denis & Schiffermüller; *Cnethocampa pityocampa*; *Thaumetopoea wilkinsonii* Tams
Order and Family: Lepidoptera: Thaumetopoeidae
Common names: oak processionary moth

Thaumetopoea processionea Linnaeus, 1758 is a major defoliating pest of oak in Europe. Native to central and southern Europe, its range has been expanding northwards where it is causing significant problems in other European countries.

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Oak processionary caterpillars, Thaumetopoea processionea

DISTRIBUTION

Native: Europe (central and southern)
Introduced: Europe (northern): Its distribution is expanding northwards and it is now firmly established in Belgium, northern France and the Netherlands, and has been reported from southern Sweden and the United Kingdom.

IDENTIFICATION

Adults have a wingspan of 30 to 32 mm and grey forewings with white and some darker grey markings (UK Forestry Commission, n.d.).

Newly hatched larvae have a uniformly brown body and dark head which lightens as they grow to become greyer in colour (UK Forestry Commission, n.d.). These mature larvae have a single dark stripe on the middle of the back and a whitish stripe along each side. The length of the body is covered by thousands of short hairs and reddish-orange warts with clumps of very long white hairs.

HOSTS

Oak trees (*Quercus* spp.) are the main hosts, but other broadleaved trees such as hornbeam (*Carpinus* spp.), hazel (*Corylus* spp.), beech (*Fagus* spp.), sweet chestnut (*Castanea* spp.) and birch (*Betula* spp.) have also been attacked by this pest, mainly when they are grown next to severely defoliated oaks.

BIOLOGY

Thaumetopoea processionea has one generation per year (Dajoz, 2000). Females lay their eggs, between 100 to 200, from July to early September on twigs and small branches in the canopy (UK Forestry Commission, n.d.). They are deposited in groups forming plaques of a single layer of eggs which are covered with greyish scales and remain on the branches over the winter.

Larvae can be found from April to June. They feed in groups and congregate in communal white silk nests under branches or on the trunk when not feeding. Larval nests are typically small, about the size of a tennis ball, but much larger ones have been reported. The larvae pass through 6 to 10 instars, shedding their skin inside the nests between each stage as they grow (UK Forestry Commission, n.d.; Dajoz, 2000). The cast skins and hairs accumulate in the nests leading them to take on an orange-brown colour over time. The larvae typically migrate in procession; following one another head-to-tail in long lines to and from the nest and from one feeding position to another, which gives rise to the common name.

Pupation takes place in the nest typically during late June or early July (UK Forestry Commission, n.d.). Adults typically emerge in August. They are nocturnal and live for only a day or two (Dajoz, 2000).

SYMPTOMS AND DAMAGE

Larvae feed on the leaves of host trees causing significant defoliation. Trees are not usually killed but repeated attacks can severely reduce health and vigour.

Thaumetopoea processionea larvae have urticating hairs that can cause skin irritation, conjunctivitis, respiratory congestions and asthma in humans. Contact with dead larvae, cocoons, nests and debris from infested oak forests can also cause dermatitis and other symptoms throughout the year. These hairs are also carried on air currents and therefore direct contact is not necessary to cause health problems. The oak processionary moth tends to be more abundant on urban trees and along forest edges where there is a high probability of it coming into contact with people.

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Oak branch defoliated by Thaumetopoea processionea

DISPERSAL AND INTRODUCTION PATHWAYS

Adult males are strong fliers and are thus capable of natural dispersal to new areas. Larval processions are also known to travel some distance to find suitable hosts.

Important possible pathways of introduction include the movement of nursery stock, live oak trees, branches and roundwood (with bark) which is infested with the eggs or even larvae.

CONTROL MEASURES

If detected, egg masses can be destroyed before they hatch the following spring. The application of biological pesticides against the larval stages soon after they hatch in the spring can be effective. Destruction of the nests during the brief pupal stage in the summer can reduce the number of adult moths that will emerge. Debarking of roundwood can help prevent the spread of this pest to new areas.

A number of species are known enemies of the oak processionary moth (Dajoz, 2000). Non-specific predators include the beetles *Xylodrepa quadripunctata*, *Calasoma sycophanta* and *C. inquisitor*, the heteropterans *Picromerus bidens* and *Troilus luridus*, and the dipteran predator *Xanthandrus comptus*. Non-specific parasitoids include species of flies such as *Ctenophorocera pavida*, *Zenilia libatrix*, *Phorocera agilis* and *Compsilura concinnata*, and the wasps, *Pimpla examinator*, *Theronia atalantae* and *Trichogramma*, *Anastatus* and *Phobocampe* species. The dipteran *Carcelia processioneae* is a host specific parasite. Other predators include some species of birds and small mammals.

DISEASES

Armillaria mellea

Other scientific names: *Agaricus melleus* Vahl; *Agaricus sulphureus* Weinm.; *Armillaria mellea* var. *glabra* Gillet; *Armillaria mellea* var. *maxima* Barla; *Armillaria mellea* var. *minor* Barla; *Armillaria mellea* var. *sulphurea* (Weinm.) Fr.; *Armillariella mellea* (Vahl) P. Karst.; *Clitocybe mellea* (Vahl) Ricken; *Lepiota mellea* (Vahl) J.E. Lange
Phylum, Order and Family: Basidiomycota: Agaricales: Marasmiaceae
Common names: Armillaria root disease; honey mushroom; shoestring root rot

Armillaria mellea (Vahl) P. Kummer is a common worldwide pathogen of trees, woody shrubs and herbaceous plants causing root rot, root-collar rot and butt rot. A natural component of forest ecosystems, it can cause wood decay, growth reduction and even mortality, particularly in trees stressed by other factors, or in young trees planted on sites from which infected hosts have been removed.

Armillaria mellea *fruiting bodies*

DISTRIBUTION

Global, found throughout temperate and tropical regions of the world.

IDENTIFICATION

The following description refers to *Armillaria* species in general (Williams *et al*., 1986). *Armillaria* can be detected by removing the bark covering an infected area to expose characteristic, fan-like sheets of white mycelium or rhizomorphs that grow between the wood and the bark. The hyphae grow together in bundles that give this mycelial mat a striated appearance. The bundles can enlarge, darken and harden into rhizomorphs. The rhizomorphs are flat, black to reddish brown in colour, up to 5 mm in width with an outer layer of dark mycelium and an inner core of white mycelium. Rhizomorphs can also grow through the soil although these tend to be more cylindrical than and approximately half as wide as those produced beneath the bark. The rhizomorphs and mycelial fans can leave impressions on the inner bark, allowing diagnosis even after they decompose.

Mushrooms growing in clusters around the bases of infected trees or stumps may indicate the presence of *Armillaria.* These short-lived mushrooms, produced sporadically in late summer or autumn, are most abundant during moist periods. They are approximately 5 cm tall with yellow or brown stalks and a ring around the stalk just below the gills is sometimes evident. The caps are honey-yellow or tan-brown in colour, 5 to 12.5 cm in diameter with slightly sticky, brown tufted hairs and light-coloured gills beneath which produce millions of white to light yellow basidiospores.

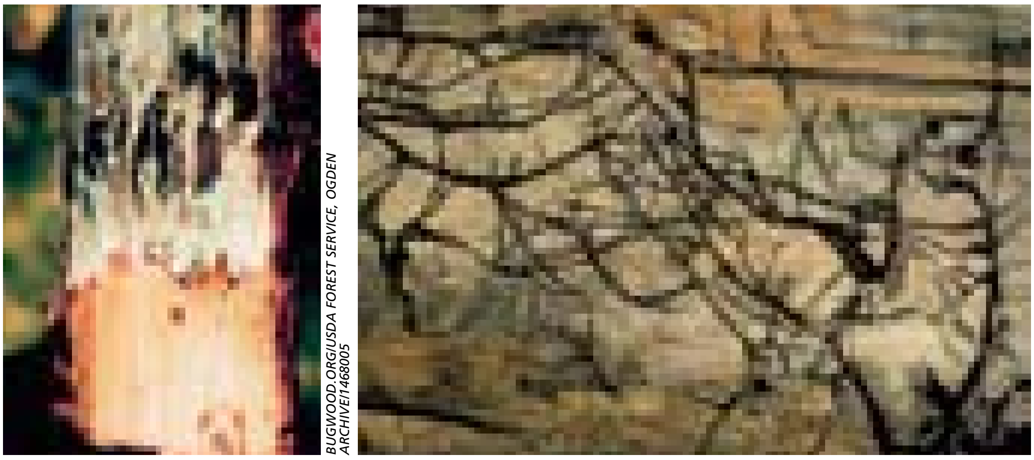
HOSTS

Armillaria mellea has a very wide host range of both broadleaf and conifer trees and also herbaceous plants.

BIOLOGY

The following description refers to *Armillaria* species in general (Sinclair and Lyon, 2005). The fungus survives as rhizomorphs and vegetative mycelium on and in the dead wood of tree stumps and roots. It has sometimes been found living several feet above the soil line on the trunk of trees several years after they are killed by *Armillaria*.

In late autumn, mushrooms may arise from the rhizomorphs and release millions of basidiospores which are carried by the wind to dead stumps or injured bark on living plants. Under favourable conditions of moisture and temperature, the basidiospores germinate and produce a mycelium that first infects the bark and then the sapwood and cambial regions. White mycelial mats develop on the sapwood, followed by the formation of rhizomorphs which can grow for distances of up to 3 m through the soil. Infection occurs when the mycelium comes in contact with and adheres to the roots of a susceptible host by means of a gelatinous secretion. The rhizomorph penetrates the root by a combination of mechanical pressure and enzymes that partially digest the root's cell walls and then grows into the root tissue between the cells. Once a host tree or plant has been invaded, the fungus continues to spread through the root and trunk tissues even several years after it has died; a large stump can support the growth of rhizomorphs for decades. Depending on environmental conditions and vigour, host trees or shrubs may die one to several years after the initial infection.



Peeling back the bark of trees infected with Armillaria mellea *exposes mycelial fans (L) and rhizomorphs (R)*

SYMPTOMS AND DAMAGE

Since *Armillaria mellea* commonly inhabits the roots of host trees and plants, detection of this species and differentiation of aboveground symptoms from other root and trunk fungi is difficult. However the presence of characteristic mushrooms growing around the bases of host trees or obvious symptoms in the crown or on the lower stem help to identify this pathogen (Williams *et al.*, 1986).

Symptoms of *A. mellea* infestation include premature autumn colouration and leaf drop, stunting of growth, yellowing or browning of the foliage, a general decline in the vigour of the host tree or plant, and dieback of twigs, branches and main stems (University of Illinois Extension, 2000). Large, vigorous or lightly infected trees can develop crown symptoms over a number of years until the trees die while small, extensively infected or low vigour trees develop symptoms rapidly, foliage quickly discolours and the host tree often dies within a year (Williams *et al.*, 1986). Conifers frequently produce a larger cone crop (stress cones) shortly before they die. As host tree decline progresses, rotting of the buttress roots and the lower trunk becomes evident and severely infected trees exude resin, gum or a fermenting watery liquid from the lower trunk (University of Illinois Extension, 2000).

On conifers, lower stem infections appear as enlarged areas with large amounts of resin flow while on broadleaved trees they sometimes develop as sunken cankers covered with loose bark or a combination of bark, gum and other resins (Williams *et al.*, 1986). Root infections are frequently heavily coated with resin, soil and sometimes fungal tissue.

DISPERSAL AND INTRODUCTION PATHWAYS

Armillaria can live for decades in suitable live host material, stumps and root fragments, and can disperse naturally through the spread of rhizomorphs in the soil (Williams *et al.*, 1986). The movement of infected plants, trees and soil can spread the pathogen to new areas.

CONTROL MEASURES

Due to the worldwide distribution and wide host range of *Armillaria mellea*, eradication is not feasible. Control measures focus on limiting the buildup of the disease or reducing its impact (Williams *et al.*, 1986). Cultural practices, such as reforesting stands with a mixture of suitable, *Armillaria* free species, maintaining vigorous tree growth, minimizing tree stress, preventing tree damage, and reducing the availability of food by uprooting and burning infected or susceptible root systems and stumps, may help with managing *Armillaria* in commercial forests and urban landscapes (Williams *et al.*, 1986). Individual high value trees can be treated with fungicides around the base of infected stems or in holes left after trees have been uprooted (Williams *et al.*, 1986).

Botryosphaeria dothidea

Other scientific names: *Caumadothis dothidea* (Moug.) Petr.; *Dothiorella mali* var. *fructans* Dearn.; *Sphaeria dothidea* Moug.
Phylum, Order and Family: Ascomycota: Dothideales: Botryosphaeriaceae
Common names: Botryosphaeria canker

Botryosphaeria dothidea (Moug.) Ces. & De Not. (1863) is known in many parts of the world and is commonly associated with cankers and dieback on hundreds of different woody plants, including eucalypts. Eucalypt species are planted around the world which makes this species a major concern to the forest sector. This pathogen is an opportunistic pathogen that attacks stressed trees. The entire taxonomy of the genus *Botryosphaeria* has undergone changes in the last few years (see Crous *et al*., 2006 for more information). This species was previously considered synonymous with *Botryosphaeria ribis*, so literature on both species is inextricably intertwined, but these are now considered two distinct species.

Cankers caused by Botryosphaeria dothidea *on apple (*Malus *sp.) (L) and Leyland cypress (X* Cupressocyparis leylandii*) with bark removed (R)*

DISTRIBUTION

Botryosphaeria dothidea has a worldwide distribution. The origin of this species is unknown although it has been suggested that it is native to the Northern Hemisphere since it occurs on native and cultivated hosts there (Slippers *et al*., 2005).

IDENTIFICATION

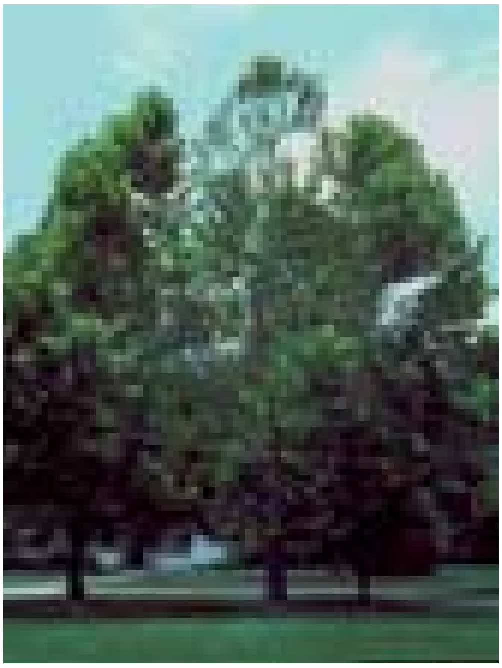
A more detailed description of the morphology of *Botryosphaeria dothidea* can be found in Slippers *et al*. (2004), Crous *et al*. (2006) or CREM (2008).

Asci are produced in fruiting bodies called stroma that erupt through the bark and have multi-layered walls. The fruiting bodies occur singly or in clusters, often intermixed with conidiomata, and are 200 to 500 µm in diameter (Slippers *et al*., 2004; Crous *et al*., 2006). Asci have two layers (bitunicate) and the inner layer is quite thick.

They can be stalked or not stalked, club-shaped, with a well-developed apical chamber, eight-spored, septate and rarely branched toward the tip (Slippers *et al*., 2004; Crous *et al*., 2006). Ascospores are unicellular, hyaline, fusoid to ovoid and sometimes have tapered ends giving a spindle-shaped appearance (Slippers *et al*., 2004; Crous *et al*., 2006). Once germinated, they turn brown and become septate and even slightly bumpy (Crous *et al*., 2006).

The pathogen is often diagnosed by the conidial state, *Fusicoccum aesculi* Corda. Conidiomata are flask-shaped and morphologically indistinguishable from the ascomata (Slippers *et al*., 2004). Conidia are hyaline, unicellular, narrowly fusiform or irregularly fusiform with subtruncate to bluntly rounded bases, 23 to 25 μm in length and 4 to 5 μm in diameter and rarely have septums (Slippers *et al*., 2004). Conidiogenous cells are holoblastic, hyaline, subcylindrical and 6 to 20 μm in length and 2 to 5 μm in diameter (Slippers *et al*., 2004).

Spermatia are unicellular, hyaline, allantoid to rod-shaped and 3 to 6 μm in length and 1.5 to 2 μm in diameter (Slippers *et al*., 2004). Spermatophores are hyaline, cylindrical to subcylindrical, 4 to 10 μm in length and 1 to 2 μm in diameter (Slippers *et al*., 2004).



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*Crown thinning and dieback in American sycamore (*Platanus occidentalis*) and apple (*Malus *sp.) caused by* Botryosphaeria dothidea *infection*

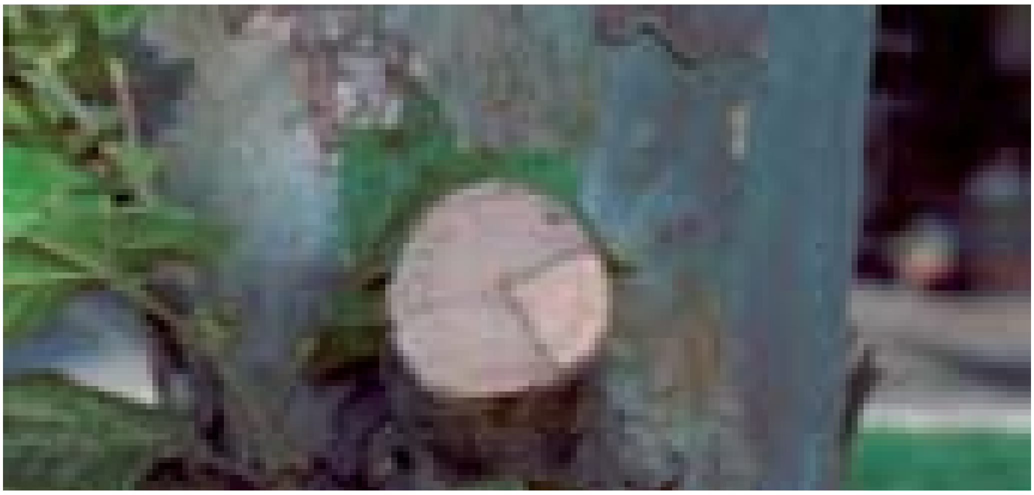
HOSTS

Botryosphaeria dothidea has a very wide host range of trees and shrubs. It is a major problem in planted forests particularly those planted with eucalypts, but susceptibility differs among the eucalypt species.

BIOLOGY

Botryosphaeria dothidea is an opportunistic pathogen that becomes more of a problem to stressed hosts. The pathogen infects through wounds or natural openings in the bark, and survives endophytically until the host becomes stressed by drought, late frosts, cold or hot winds, insect damage or pruning (TPCP, 2002a; Sinclair and Lyon, 2005).

Botryosphaeria dothidea overwinters in dead and infected stems. Spores are dispersed by wind, rain and possibly insects to new hosts where they germinate and invade the host tissues. Pruning wounds are a common infection court. Fungal fruiting bodies produced just under the surface of stems release spores which spread to adjacent hosts. Except for a few weeks in winter, spores are released year-round although infections occur more frequently in early summer.



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*Discolouration of the vascular tissue of American sycamore (*Platanus occidentalis*) caused by* Botryosphaeria dothidea *infection; only the light-coloured section (¼) is alive*

SYMPTOMS AND DAMAGE

Botryosphaeria dothidea causes dieback and canker in hundreds of woody plants and trees. On some hosts, only small twigs die, especially if the host is vigorous. Stressed trees may be unable to compartmentalize the infection, and the dieback progresses into larger branches and trunk.

In *Eucalyptus* spp. infection can result in the death of tree tops and a discolouration of the stem core which can extend throughout the tree (TPCP, 2002a). Stem and branch cankers are very serious symptoms of *B. dothidea* infection; the stems and branches often break at the site of the cankers (TPCP, 2002a).

DISPERSAL AND INTRODUCTION PATHWAYS

Spores are dispersed by wind, rain and possibly insects to new hosts. Movement of infected trees, plants and wood products is a possible pathway of introduction.

CONTROL MEASURES

Encouraging vigourous growth and reducing damage to susceptible host trees can help avoid infection by *Botryosphaeria dothidea.* Removal of pruned or fallen branches can reduce inoculum. Early detection and the planting of disease tolerant species or clones can help reduce losses in forest plantations (TPCP, 2002a).

Chrysoporthe cubensis

Phylum, Order and Family:: Ascomycota: Diaporthales: Incertae sedis
Common names: *Eucalyptus* canker; *Eucalyptus* canker disease

Chrysoporthe cubensis (Bruner) Gryzenhout & M.J. Wingfield, previously named *Cryphonectria cubensis* (Bruner) Hodges, is a widespread fungus well known for the canker disease it causes, particularly in *Eucalyptus* spp. The cankers result in limb and trunk breakages, stunted and distorted growth, and often mortality. This is a very important disease in eucalypt plantations as it is known to kill significant numbers of trees, particularly those in young plantations, and as a result it is a major constraint to the successful establishment of eucalypt plantations.

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Fruiting bodies of Chrysoporthe cubensis*: perithecia embedded in and protruding from bark removed from cankered tissues of* Eucalyptus grandis

DISTRIBUTION

The geographic origin of this pathogen is unknown. The original host is thought to be clove (*Syzygium aromaticum*) which is native to Indonesia (Myburg, Wingfield and Wingfield, 1999). However, others have suggested that *C. cubensis* is native to South and Central America based upon its wide occurrence in the region, its high phenotypic diversity in various South America countries and the discovery of this pathogen on native *Miconia* species in Colombia (Gryzenhout *et al*., 2006).

It is found throughout tropical and subtropical regions of the world including Brazil, Colombia, Cuba, Mexico, Suriname, Venezuela, United States (Florida, Hawaii, Puerto Rico), Cameroon, Democratic Republic of Congo, Republic of Congo, United Republic of Tanzania (Zanzibar), Australia, China, India, Indonesia, Malaysia, Singapore and Western Samoa (Gryzenhout *et al*., 2004).

IDENTIFICATION

Detailed descriptions of the morphology of *Chrysoporthe cubensis* can be found in Gryzenhout *et al*. (2004) and Myburg *et al*. (2004).

Conidiomata of *Chrysoporthe cubensis* occur separately or on the top of an ascostroma and are distinguishable from ascomata by their pyriform shape, attenuated necks, conidiomatal locules and distinct stromatic tissue (Gryzenhout *et al*., 2004). They are generally superficial, black, pyriform to globose with attenuated necks (Gryzenhout *et al*., 2004; Myburg *et al*., 2004). Conidiophores are hyaline and consist of a globular to rectangular basal cell that branches irregularly at the base or above into cylindrical cells (Gryzenhout *et al*., 2004). Conidia are hyaline, non-septate, oblong, and secreted as bright spore tendrils or droplets (Gryzenhout *et al*., 2004).

Ascomata are semi-immersed in the bark and are recognizable by extending, fuscous-black, cylindrical perithecial necks (Gryzenhout *et al*., 2004; Myburg *et al*., 2004). Ascostroma stand 120 to 230 µm above the level of bark and are 280 to 490 µm in diameter (Gryzenhout *et al*., 2004). Ascospores are fusoid to oval with a septum that is usually central and tapered apices (Gryzenhout *et al*., 2004; Myburg *et al*., 2004).

HOSTS

Species from the Myrtaceae, Melastomataceae and Lythraceae families including *Syzygium aromaticum*, *Melastoma malabathricum*, *Lagerstroemia indica*, *Clidemia sericea*, *Rhynchanthera mexicana*, *Psidium cattleianum* and species of *Eucalyptus*, *Tibouchina* and *Miconia*.

BIOLOGY

Chrysoporthe cubensis infects trees through wounds, particularly at the bases of young trees. The most common method of infection is believed to be through asexual spores that are dispersed by rain splash although wind disseminated sexual spores are also common (TPCP, 2002b). Infection is favoured by warm temperatures and rainfall (Myburg, Wingfield and Wingfield, 1999). Lesions expand more rapidly in plants that are well-watered than in those where the soil or climate is relatively dry (Sinclair and Lyon, 2005).


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Symptoms and damage caused by Chrysoporthe cubensis *on* Eucalyptus grandis*: bark fissures at the base of infected tree (L) and advanced canker development (R)*

SYMPTOMS AND DAMAGE

Chrysoporthe cubensis causes a canker disease which results in girdling of stems, limb and trunk breakages, stunted and distorted growth, wilting and often mortality (Gryzenhout *et al*., 2004; Nakabonge *et al.*, 2006). This is a very important disease in eucalypt plantations as it is known to kill significant numbers of eucalypts, particularly those in young plantations. The cankers can be found at the bases of hosts or higher up on the trunks (Nakabonge *et al.*, 2006).

DISPERSAL AND INTRODUCTION PATHWAYS

The movement of infected plants and trees can spread the pathogen to new areas.

CONTROL MEASURES

Breeding for disease-tolerant eucalypt hybrids has been successful in managing the disease caused by *Chrysoporthe* spp. in some countries, such as Brazil and South Africa (Nakabonge *et al.*, 2006). Planting of disease tolerant eucalypts, and avoiding planting in high risk areas, can help reduce losses in plantations (TPCP, 2002b).

Mycosphaerella pini

Other scientific names: *Cytosporina septospora* Dorog.; *Dothistroma pini* Hulbary; *Dothistroma pini* var. *keniense* M.H. Ivory [as *'keniensis'*]; *Dothistroma pini* var. *lineare* Thyr & C.G. Shaw; *Dothistroma septosporum* (Dorog.) M. Morelet [as *'septospora'*]; *Dothistroma septosporum* var. *keniense* (M.H. Ivory) B. Sutton; *Dothistroma septosporum* var. *lineare* (Thyr & D.E. Shaw) B. Sutton; *Dothistroma septosporum* var. *septosporum* (Dorog.) M. Morelet; *Eruptio pini* (Rostr.) M.E. Barr; *Mycosphaerella pini* (A. Funk & A.K. Parker) Arx; *Scirrhia pini* A. Funk & A.K. Parker; *Septoria septospora* (Dorog.) Arx; *Septoriella septospora* (Dorog.) Sacc.
Phylum, Order and Family: Ascomycota: Capnodiales: Mycosphaerellaceae
Common names: pine needle blight; dothistroma needle blight; needle fungus; red band needle blight

Mycosphaerella pini Rostrup, 1957 is a fungus that infects and kills the needles of *Pinus* spp. resulting in significant defoliation, stunted growth and eventually death of host trees. It is a major pest in both naturally regenerated and planted forests and probably the most important foliage disease of exotic pines. Susceptibility among pine species does vary. The widely planted *P. radiata* is particularly susceptible and many forests planted with this species in the Southern Hemisphere, particularly in East Africa, New Zealand and Chile, have been devastated by this needle blight. This pathogen has forced managers in some areas to abandon the planting of *P. radiata* and depend more on other tree species.


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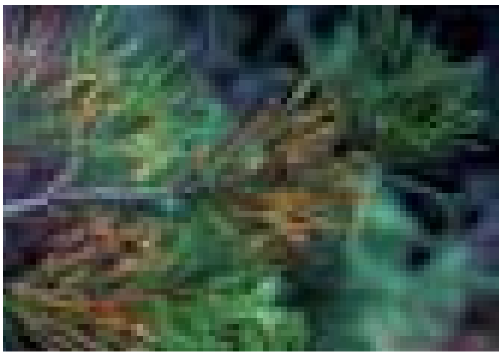
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Red transverse bands on pine needles are a characteristic symptom of Mycosphaerella pini *infection*

DISTRIBUTION

Mycosphaerella pini is believed to be native to the cloud forests of Central America though it now has a worldwide distribution (EPPO/CABI, 1997).

IDENTIFICATION

Ascostromata are black, multiloculate, subepidermal, erumpent, 200 to 600 x 95 to 150 µm in size and densely aggregated in red bands (EPPO/CABI, 1997; Hildebrand, 2005).
Asci are cylindric or clavate, bitunicate, apex rounded, eight-spored, and 46 to 52 x 8 to 10 µm in size (Hildebrand, 2005). Ascospores are hyaline, with one septum, fusiform to cuneate, and 13 to 16 x 3 to 4 µm in size (Hildebrand, 2005).

The conidial state is known as *Dothistroma septosprum*. Conidial stromata are linear, subepidermal, erumpent, dark brown or black, 125 to 1500 µm long, 5 to 45 µm wide and up to 600 µm high (Hildebrand, 2005). Conidial locules are parallel to the longitudinal axis of stromata and lack a distinct wall (Hildebrand, 2005). Conidiophores are numerous, hyaline or amber, dense, unbranched and are approximately the same size as the conidia which they produce at their tips (Hildebrand, 2005). Conidia are hyaline, one- to five- but usually three-septate, blunt at the ends, straight, slightly curved or bent and 16 to 64 x 3.5 µm in size (Hildebrand, 2005).

HOSTS

The main hosts are pines, such as *Pinus contorta*, *P. echinata*, *P. jeffreyi*, *P. monticola*, *P. muricata*, *P. pinaster*, *P. ponderosa*, *P. radiata*, *P. resinosa*, and *P. sylvestris*, although other species such as *Picea abies*, *Picea sitchensis*, *Pseudotsuga menziesii* and *Larix decidua* have been infected (EPPO/CABI, 1997).

BIOLOGY

Mycosphaerella pini produces both conidia and ascospores although the conidial state is most frequently encountered (Hildebrand, 2005). Numerous conidia are produced in the stromata (fruiting bodies) which develop below the epidermis of infected needles (Peterson, 1982). Stromata can remain viable on dry infected foliage for many months and will produce conidia when suitable moist conditions arise (Hildebrand, 2005). Conidia are dispersed short distances by rain splash and longer distances by wind-dispersed moisture droplets, mist and low clouds (EPPO/CABI, 1997; Hildebrand, 2005). Optimum temperatures for spore germination are between 18 and 24 °C (Hildebrand, 2005). After germination, germ tubes grow toward the stomata through which infection occurs. The fungus grows within the needle tissue and kills cells with the toxin, dothistromin, in advance of the growing hyphae (Hildebrand, 2005). Dead needles remain attached to the host tree and produce spores for approximately one year (Hildebrand, 2005).

SYMPTOMS AND DAMAGE

Mycosphaerella pini is a fungus that infects and kills the needles of many *Pinus* spp. resulting in premature loss of needles and significant defoliation. Damage by *Mycosphaerella pini* has significant impacts on commercial forests, Christmas tree plantations and nurseries. This pathogen can spread rapidly when environmental conditions, mild climate with high rainfall or frequent fog or mist, favour infection.

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Symptoms of Mycosphaerella pini *infection on* Pinus nigra

Infected host trees typically have thin crowns with discoloured and dead needles, especially on the lower crown (Hildebrand, 2005). Early symptoms are the presence of yellow to tan spots on needles which later turn brown or reddish brown and enlarge to produce the characteristic red band around the needle (Peterson, 1982; Hildebrand, 2005). These red bands are diagnostic for this disease and are caused by the presence of dothistromin, a toxin produced by *M. pini* (Hildebrand, 2005). The ends of infected needles eventually turn brown but the bases of the needles remain green (Peterson, 1982; Hildebrand, 2005). Small black fruiting bodies break through the needle epidermis in the centre of the red band (Hildebrand, 2005). Infected needles die and drop prematurely typically leaving branches with only terminal needles remaining (Hildebrand, 2005). Older needles are typically cast before younger needles. The development of epicormic shoots on the stem and major branches of infected host trees may also occur (EPPO/CABI, 1997). Host trees can be defoliated within weeks and successive years of infection results in stunted growth and eventual mortality.

DISPERSAL AND INTRODUCTION PATHWAYS

Mycosphaerella pini produces numerous conidia that can be dispersed short distances by rain splash; long distance dispersal is often through wind dispersed moisture droplets, mist and low cloud (EPPO/CABI, 1997; Hildebrand, 2005). Ascospores can also be wind-dispersed long distances.

Longer distance spread can occur through the movement of infected planting stock, seed mixed with small infected needle pieces and logs which have infected needles lodged in the bark crevices (EPPO/CABI, 1997; Hildebrand, 2005). Once the pathogen has been transported to new areas, it is capable of producing spores and thereby spreading to nearby suitable hosts as long as there is sufficient moisture for spore germination and infection (Hildebrand, 2005).

CONTROL MEASURES

Mycosphaerella pini has been successfully controlled through the use of copper fungicides although over large areas their use is not always economically feasible (EPPO/CABI, 1997; Hildebrand, 2005). In nurseries and Christmas tree plantings, however, fungicides can be effective and economical (Hildebrand, 2005). Pruning and the planting of less susceptible pine species or pest tolerant varieties can also help in the control of this pathogen (EPPO/CABI, 1997; Hildebrand, 2005).

Phytophthora ramorum

Phylum, Order and Family: Oomycota: Pythiales: Pythiaceae
Common names: sudden oak death (SOD); sudden oak death syndrome (SODS); ramorum blight; ramorum dieback; ramorum leaf blight; ramorum shoot blight

Phytophthora ramorum S. Werres, A.W.A.M. de Cock & W.A. Man in't Veld causes a very serious disease called sudden oak death which causes extensive mortality of tanoak and oaks. It is also associated with disease on ornamental plants and other broadleaf and conifer trees. This pathogen has been a significant problem in North American and European forests and nurseries.

*Cankers and bleeding on coast live oak (*Quercus agrifolia*) resulting from* Phytophthora ramorum *infection*

DISTRIBUTION

Native: The geographic origin of *P. ramorum* is unknown.
Introduced: It is believed that it has been introduced independently to Europe and North America from an unidentified third country.
North America: Canada (nursery report now eradicated); United States (14 counties in coastal California, one county in southwest Oregon)
Europe: Nursery reports only from Belgium, Denmark, France, Germany, Ireland, Italy, Norway, Poland, Slovenia, Spain, Switzerland, and Sweden; nursery as well as wildland reports from the Netherlands and the United Kingdom

IDENTIFICATION

In culture, *P. ramorum* hyphae are highly branched, contorted and dendritic (GISD, 2007). Chlamydospores are mostly terminal occurring on hyphal tips, 22 to 72 µm in length and at first are translucent but darken to a cinnamon brown colour (Kliejunas, 2001; GISD, 2007). Sporangia are oval-shaped, semi-papillate, deciduous and 30 to 90 µm in length (Kliejunas, 2001; GISD, 2007).

HOSTS

In the United States, *Phytophthora ramorum* attacks a variety of tree species including coast live oak (*Quercus agrifolia*), California black oak (*Q. kelloggii*), shreve oak (*Q. parvula* var. *shrevei*), canyon live oak (*Q. chrysolepis*) and tanoaks (*Lithocarpus densiflorus*) (Thomas, 2005). It is also known to infect several other plant and tree species such as Pacific madrone (*Arbutus menziesii*), poison oak (*Toxicodendron diversilobatum*), big leaf maple (*Acer macrophyllum*), coast redwood (*Sequoia sempervirens*), Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), rhododendron and azalea species (*Rhododendron*), Pacific huckleberry/evergreen huckleberry (*Vaccinium ovatum*), lingonberry (*V. vitis-idaea*), strawberry tree (*Arbutus unedo*), mountain laurel (*Kalmia latifolia*), manzanita (*Arctostaphylos manzanita*), English yew (*Taxus baccata*), dwarf rose (*Rosa gymnocarpa*), salmonberry (*Rubus spectabilis*), California coffeeberry (*Rhamnus californica*), cascara buckthorn (*Rhamnus purshiana*), beaked hazelnut (*Corylus cornuta*), Victorian box (*Pittosporum undulatum*), California buckeye (*Aesculus californica*), California bay laurel (*Umbellularia californica*), California honeysuckle (*Lonicera hispidula*), toyon/Christmasberry (*Heteromeles arbutifolia*), western starflower (*Trientalis latifolia*), *Syringa* spp., *Viburnum* spp., *Pieris* spp. and *Camellia* spp. (Kliejunas, 2001; EPPO, 2008).

In Europe, *P. ramorum* is mainly found on *Rhododendron* and *Viburnum* species, but has also been isolated from *Arbutus, Camellia, Hamamelis, Kalmia, Leucothoe, Pieris* and *Syringa* species (EPPO, 2008). In the United Kingdom, an isolated finding was reported on one *Quercus falcata* tree and on a few trees of *Fagus sylvatica, Quercus ilex*, *Q.cerris, Castanea sativa* and *Aesculus hippocastanum* (EPPO, 2008). In the Netherlands, infections on one *Q. rubra* and two *Fagus sylvatica* have been reported; all were located near infected *Rhododendron* (EPPO, 2008).

An updated list of *P. ramorum* hosts can be found on the USDA's Animal and Plant Health Inspection Service (APHIS) Web site at: www.aphis.usda.gov

BIOLOGY

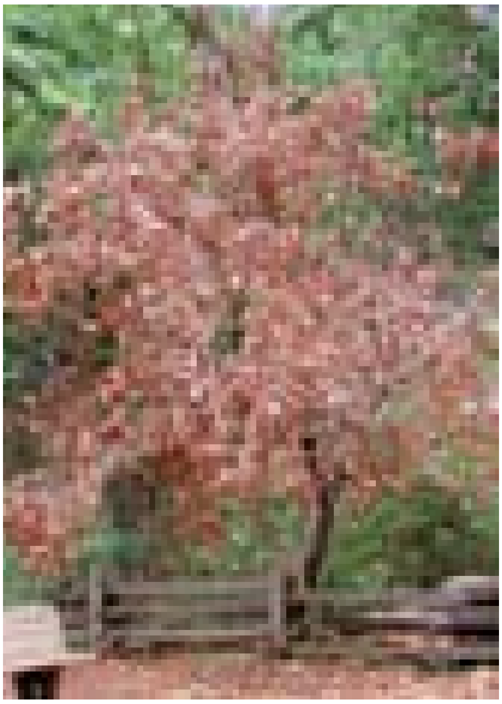
Phytophthora ramorum exists as two separate mating types: the A1 mating type (found primarily in Europe); and the A2 type (found primarily in North America) (Kliejunas, 2001). Sexual reproduction can only occur if these two types come together.

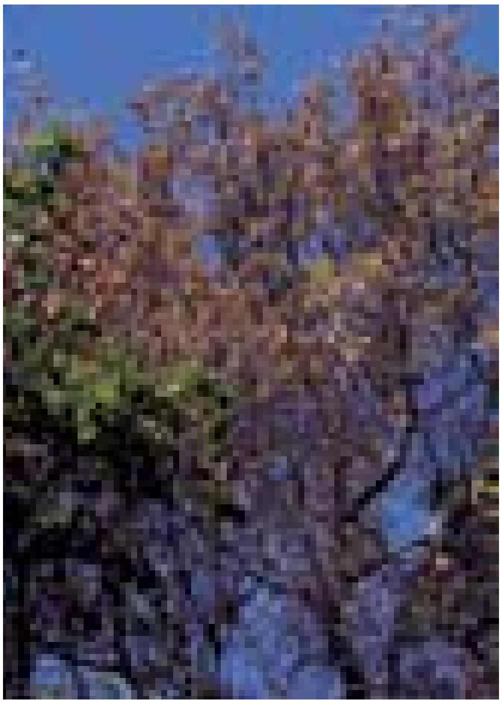
Two types of asexual fruiting structures, sporangia and chlamydospores, are produced on the foliage of non-oak hosts (Kliejunas, 2005; DEFRA, 2005a). Infected oak produce few spores while other hosts such as bay laurel and tanoak produce prolific sporulation, and are believed important in the epidemiology of the disease. The sporangia hold and produce zoospores which can swim by means of flagellae. Warm temperatures of approximately 18 to 20 °C and/or a water film facilitate infection. Leaves and twigs then develop black lesions where, in conditions of very high humidity and moderate temperature, new sporangia and chlamydospores are produced typically within two days (GISD, 2007). Chlamydospores form inside the leaf tissue, and provide a resting/survival structure that remains viable in the organic material or soil for over one year. Infectious propagules accumulate in water bodies in the soil beneath the host (GISD, 2007). Infection of the main stems of tanoaks and oaks generally occurs only under high spore pressure, usually provided by nearby sporulation hosts, such as rhododendron or bay laurel (GISD, 2007).

SYMPTOMS AND DAMAGE

Symptoms vary depending on host type. On oaks and tanoak, infection results in stem bark lesions, basal cankers which produce reddish, black or dark brown sappy exudates ('bleeding'), and crown dieback (Kliejunas, 2001; Thomas, 2005). Cankers are typically found on the lower trunk, although they may occur up to 20 m above the ground; they do not extend into the roots below the soil line (Kliejunas, 2001).

Branch cankers also occur, especially on tanoak. On tanoak, infection of terminal twigs can lead to tip dieback, leaf flagging or the formation of shepherd's crooks (Kliejunas, 2001). Exudations do not always develop on tanoak, especially on smaller diameter branches. Infected host trees die relatively quickly once crown symptoms develop although the severity of damage varies considerably between sites. On other hosts, infection typically results in leaf lesions, small branch cankers, and stem and branch dieback (Kliejunas, 2001).





Symptoms of Phytophthora ramorum *infection on tanoak (*Lithocarpus densiflorus*) and coast live oak (*Quercus agrifolia*)*

DISPERSAL AND INTRODUCTION PATHWAYS

Phytophthora ramorum is dispersed locally by rain splash, wind-driven rain, irrigation or ground water, soil and soil litter (Kliejunas, 2001; DEFRA, 2005a). The deciduous nature of the sporangia opens the possibility for air dispersal. Bark and ambrosia beetles are commonly found on infected trees but their potential role of vectors has not yet been investigated (EPPO, 2008).

Spread over longer distances occurs through the movement of contaminated plant material, growing media and nursery stock as well as in soil carried on vehicles, machinery, footwear or animals (Kliejunas, 2001; DEFRA, 2005a).

CONTROL MEASURES

Trunk painting with Agri-Fos, a systemic fungicide, has effectively prevented infection on high value trees. This material provides some curative action, if the infection is not too far advanced. An active eradication program, requiring the removal of all host material with a buffer strip of 30 m has greatly reduced the spread of the pathogen in Oregon. In California, and in nurseries, the focus is on preventing the further spread through careful monitoring and detection methods and quarantine procedures.

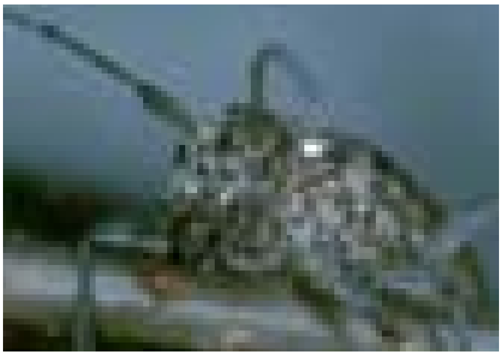
In natural areas heavily infested with *P. ramorum* eradication is not feasible. Small infestations can be eradicated if the pathogen is detected early enough, by removing all infected or suspect host material, with a large buffer zone, treating stumps to prevent resprouting, and broadcast burning to kill inoculum in the plant debris and leaf litter (COMTF, 2008). In nurseries, the application of fungicides, the planting of host resistant plants and cultural control methods such as pruning, destruction of affected plants, avoiding standing water and careful examination of plants can help to decrease the incidence of *P. ramorum* (DEFRA, 2005b; Benson, 2003).

OTHER PESTS

Bursaphelenchus xylophilus

Other scientific names: *Aphelenchoides xylophilus* Steiner & Buhrer; *Bursaphelenchus lignicolus* Mamiya & Kiyohara
Order and Family: Tylenchida: Aphelenchoididae
Common names: pine wood nematode; pine wilt nematode; pine wilt disease

Bursaphelenchus xylophilus (Steiner & Buhrer) Nickle, the pine wilt nematode, is the causal agent of pine wilt disease. Native to North America where it is not considered a serious pest, the nematode is a major threat to Asian and European pine forests and has resulted in extensive tree mortality in countries where it has been introduced.



Species of Monochamus *serve as vectors for the pine wilt nematode,* Bursaphelenchus xylophilus

DISTRIBUTION

Native: North America (Canada, Mexico, United States)
Introduced: Asia and the Pacific: Hong Kong (1999); Japan (early 1990s, first record in 1905), People's Republic of China (1982), Republic of Korea (1988)
Europe: Portugal (1999)

IDENTIFICATION

B. xylophilus shows the general characters of *Bursaphelenchus* spp. with lips high and offset, a weakly developed stylet with reduced basal knobs, well developed median bulb with a dorsal oesophageal gland opening inside (EPPO/CABI, 1997; Shi, 2005). The female's post-uterine sac is long and in males, the tail is curved ventrally, conoid and has a pointed terminus. A small bursa is situated terminally and spicules are well developed, with a prominent rostrum. Characteristics distinct to the species *B. xylophilus* include: spicules in males are flattened into a disc-like structure (the cucullus) at their distal extremity; the anterior vulval lip in the female is a distinct overlapping flap; and the posterior end of the body is rounded in nearly all females (EPPO/CABI, 1997; Shi, 2005).

HOSTS

Pines are the main hosts and the dead wood of all pines can provide substrate for nematode development. Examples of species susceptible to attack as living trees include *Pinus bungeana*, *P. densiflora*, *P. echinata*, *P. luchuensis P. massoniana*, *P. nigra*, *P. palustris P. pinaster*, *P. strobus*, *P. sylvestris* and *P. thunbergii* (EPPO/CABI, 1997; Diekmann *et al*., 2002). *Larix*, *Abies*, *Picea* and *Pseudotsuga* species can also act as hosts though reports of damage are rare (EPPO/CABI, 1997).

BIOLOGY

The spread of this nematode is via wood-boring beetles in the genus *Monochamus*: *M. alternatus* in China, Korea and Japan, *M. carolinensis*, *M. scutellatus* and *M. titillator* in North America (Diekmann *et al*., 2002; Shi, 2005) and *M. galloprovincialis* in Portugal. They become infested with the nematode just before emerging as adults from diseased host trees. Adult beetles can act as vectors for thousands of nematodes. The beetles fly to healthy pines where they feed on the thin bark of twigs and shoots. The nematode enters the trees via the feeding wounds created by the beetles. They feed on fungi and multiply in the host trees. Pine wilt disease is most prevalent in warm climates as the nematode completes its life cycle in 12, 6 and 3 days at 15 °C, 20 °C and 30 °C, respectively (Diekmann *et al*., 2002).

SYMPTOMS AND DAMAGE

Within host trees, the pine wilt nematodes reproduce rapidly and the infested trees show symptoms of decline approximately three weeks later (Kiritani and Morimoto, 2004). Initial symptoms appear in summer through early autumn, and include yellowing and

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Damage caused by the pine wilt nematode including needle discolouration, reddish crowns and stained wood needle wilting. Dead trees characteristically exhibit reddish-brown foliage throughout the crown. No oleoresin flows from wounds made to the trunk, branches or twigs of diseased trees which is a first indication of the presence of nematodes (Diekmann *et al*., 2002; Kiritani and Morimoto, 2004).

Usually trees die rapidly, but in cooler areas disease development may be slower and affected trees may survive until the following year. High temperatures and low precipitation in summer can accelerate damage because of their impacts on feeding by the adult beetle vectors, the propagation of the nematode and water stress on trees (Kiritani and Morimoto, 2004). In Asia, infected trees have been noted to die within 40 days and the entire pine forest invaded by the nematode declines in 3 to 5 years (Shi, 2005). Kiritani and Morimoto (2004) noted that most infected trees die within a year of infection in warm temperate climatic zones.

DISPERSAL AND INTRODUCTION PATHWAYS

Without their vectors, pine wilt nematodes are incapable of moving from one host tree to another. Adult vector beetles are active fliers and peak flight activity is usually about 5 days after emergence. It has been reported that the beetles are capable of flying several kilometers, but in most cases dispersal is only for a few hundred metres (EPPO/CABI, 1997). Long-distance spread occurs with movement of vector-infested logs and other wood products (Diekmann *et al*., 2002).

CONTROL MEASURES

Once introduced into a tree *B. xylophilus* is considered impossible to control. Therefore efforts have concentrated on prevention and a combination of silvicultural practices, such as removing dead or dying trees from the forest to help eliminate the source of further infection, and chemical control aimed at the vector beetles. Preventative measures applied in North America include avoiding the planting of non-native pines in areas where the mean summer temperature is greater than 20 °C and reducing the susceptibility of trees by fertilizing and watering to avoid drought stress, promote tree health and reduce the chances of borer attack (Shi, 2005). Research on alternative control measures, such as biological control agents for the nematodes and their vectors, insect attractants, breeding of resistant *Pinus* clones and inducing resistance by inoculation of non-pathogenic strains of *B. xylophilus*, is ongoing (EPPO/CABI, 1997; Kiritani and Morimoto, 2004).

Listed as an A1 quarantine pest by EPPO, regulations have been imposed on United States and Canadian shipments of unprocessed coniferous wood products since the early 1990s (EPPO/CABI, 1997). To prevent the introduction of *B. xylophilus* and its vectors EPPO recommends that coniferous plants and products should be prohibited from countries where the nematode occurs. The international standard ISPM No. 15 provides guidelines for regulating wood packaging materials in international trade to prevent the introduction of forest pests including *B. xylophilus*.

PART III

Pests of selected forest tree species

Abies grandis

Order and Family: Pinales: Pinaceae
Common names: grand fir; giant fir

NATURAL DISTRIBUTION

Abies grandis is a western North American (both Pacific and Cordilleran) species (Klinka *et al*., 1999). It grows in coastal (maritime) and interior (continental) regions from latitude 39 to 51 °N and at a longitude of 125 to 114 °W. In coastal regions, it grows in southern British Columbia (Canada), in the interior valleys and lowlands of western Washington and Oregon (United States), and in northwestern California (United States). Its range extends to eastern Washington, northern Idaho, western Montana, and northeastern Oregon (Foiles, 1965; Little, 1979). This species is not cultivated as an exotic to any significant extent.

PESTS

Arthropods in indigenous range

The western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir tussock moth (*Orgyia pseudotsugata*) have caused widespread defoliation, top kill and mortality to grand fir. Early-instar larvae of *C. occidentalis* mine and kill the buds, while late-instar larvae are voracious and wasteful feeders, often consuming only parts of needles, chewing them off at their bases. The western balsam bark beetle (*Dryocoetes confusus*) and the fir engraver (*Scolytus ventralis*) are the principal bark beetles. Fir cone moths (*Barbara* spp.), fir cone maggots (*Earomyia* spp.), and several seed chalcids destroy large numbers of grand fir cones and seeds. The balsam woolly adelgid (*Adelges piceae*) is a serious pest of *A. grandis* in western Oregon, Washington and southwestern British Columbia (Furniss and Carolin, 1977). Feeding by this aphid causes twigs to swell or 'gout' at the nodes and the cambium produces wide, irregular annual growth rings consisting of reddish, highly lignified, brittle wood (Harris, 1978).

Diseases in indigenous range

Susceptibility to heart rot and decay is one of the more important factors in the management of *A. grandis*. Indian paint fungus (*Echinodontium tinctorium*) is the most destructive fungus affecting this species in Washington and Oregon (Hepting, 1971), but is rare where rapid growth rates close branch stubs quickly (Etheridge and Craig, 1976). *E. tinctorium* causes a brown stringy rot, but in early stages decay appears as a light-brown or water-soaked stain in the heartwood. Centres of decay are closely related to logging scars, frost cracks, broken tops and other mechanical injuries (Maloy, 1967). *Armillaria* spp. and *Phellinus weirii* are the two most important root-rot fungi (Hepting, 1971).

Acacia mangium

Order and Family: Fabales: Fabaceae
Common names: brown salwood

NATURAL DISTRIBUTION

Acacia mangium is found in northern Queensland, Australia, where it has a very limited distribution in two regions. Most occurrences are in the coastal, tropical lowlands, with small occurrences up to 800 m. It extends through the Western Province of Papua New Guinea into the Indonesian provinces of Irian Jaya and Maluku (Awang and Taylor, 1993).

PESTS

Arthropods and diseases in indigenous range

There are no significant reports.

Arthropods in introduced range

Hutacharern (1992, 1993) lists a wide range of insect pests affecting *A. mangium* and identified a stem borer (*Zeuzera coffeae*), root pests (*Coptotermes curvignathus*) and a shoot and stem girdler (*Sinoxylon* sp.) as serious pests. Insect damage to the wood by carpenter ants (*Camporatus* sp.), termites (*Coptotermes* sp.) and a Cerambycid wood borer (*Xystocera* sp.) has been recorded in localized areas in Sabah, Malaysia.

Pinhole beetles of three species (*Xyleborus perforans*, *X. crassiusculus*, and an unidentified *Xyleborus* sp.) were observed on logs of *A. mangium* during pruning studies in an industrial plantation at Surigao del Sur, Philippines (Braza, 1995). Ho and Maznah (1995) found a total of 21 species of beetles from the family Scolytidae attacking both unseasoned and seasoned *A. mangium* timber.

Diseases in introduced range

Diseases of *A. mangium* in plantations in tropical areas of Southeast Asia, the Indian subcontinent and northern Australia have been reviewed by Lenné (1992), Lee (1993) and Old, Lee and Sharma (1997).

Mehrotra *et al*. (1996) describe root and heart rots, their causal agents and potential control measures in plantations of *A. mangium* in West Bengal, India. Root rot of *A. mangium*, caused by *Ganoderma* sp. and *Phellinus* spp., affects young stands in most places where *A. mangium* is now grown. Management options include the physical removal of stumps and woody debris and possible use of fungicides. A yellow, mottled, soft, light heart rot involving a range of wood decay fungi is a potentially serious source of wood degradadation throughout all areas where the species is grown, with 50 percent of trees affected in some stands. Cankers associated with decayed branch stubs and pruning wounds are good indicators of heart rot. Infected trees can continue to grow vigorously to maturity. Management options include adopting silvicultural practices that limit wounds to the stem, including early singling of multistemmed trees, short rotations and selecting provenances for slender branches and single stems.

Other significant diseases include stem cankers involving a range of pathogens, pink disease (*Corticium salmonicolor*) and phyllode rust (*Endoraecium digitatum*).

INVASIVENESS

Acacia mangium could become a weed under certain conditions.

Casuarina equisetifolia

Order and Family: Casuarinales: Casuarinaceae
Common names: coast she-oak; whistling pine; casuarina

NATURAL DISTRIBUTION

Subsp. *equisetifolia* occurs naturally along the tropical coastlines from Northern Queensland and Northern Territory in Australia, throughout the whole Malesian region to the Kra Isthmus of Thailand and adjoining coastal areas of the Andaman Sea in southern Myanmar. Subsp. *incana* has a much narrower distribution extending from the coastlines of central New South Wales to north Queensland in Australia, and in Vanuatu and New Caledonia. Some dispersal of seed, from cones, may be affected by water, ensuring the spread of the species along sea shores. *C. equisetifolia* may form pure stands on the coastal dunes growing over a ground cover of dune grasses and broadleaved herbs, or can be part of a richer association of trees and shrubs collectively termed the Indo-Pacific strand flora (Champion, 1936; Doran and Turnbull, 1997). In Australia, it also grows in narrow belts adjacent to mangrove forests or scattered in open woodlands dominated by eucalypts.

PESTS

Arthropods and diseases in indigenous range

There are no significant reports.

Arthropods in introduced range

C. equisetifolia is a nitrogen-fixing tree of considerable social, economic and environmental importance in many tropical areas of the world. It is widely planted for reclamation of unstable coastal ecosystems in the tropics and subtropics.

Over 50 species of insects are known to feed on the species, but serious pest problems have not occurred. A borer beetle, *Sinoxylon anale*, girdles small stems (about 1 cm in diameter), causing them to break at the point of attack (Pinyopusarerk *et al*., 1996b). Seedlings are susceptible to browsing by rodents, crabs, crickets and grasshoppers. In Puerto Rico casuarina is the host for many insect species from the orders Coleoptera, Hemiptera, Isoptera, Lepidoptera and Orthoptera (Martorell, 1975). In Cuba, insects that damage in plantations include the stem and twig borer *Apate monachus*, leaf cutting ant *Atta insularis*, Australian pine spittle-bug *Clastoptera undulata* and the cottony cushion scale *Icerya purchasi*. In Florida minor damage is caused by the twig girdler *Oncideres cingulata*, the thorn bug *Umbonia crassicornis*, Australian pine spittle bug *C. undulata* and the leaf notcher weevil *Artipus floridanus*.

Diseases in introduced range

The most serious disease threatening *C. equisetifolia* is blister bark disease. Infected trees die rapidly after exhibiting symptoms of foliar wilt and cracking of the bark where blisters develop enclosing a black powdery mass of spores (Bakshi, 1976). Blister bark disease is associated with the fungus *Subramanianospora vesiculosa*. The disease was first reported in Orissa State, India. It has since been recorded in Sri Lanka, from all of the peninsular states of India, and from Mauritius and Indonesia. It has recently been observed in Thailand (Pongpanich, Luangviriyasaeng and Dudzinski, 1996) and Viet Nam (Sharma, 1994).

Bacterial wilt, associated with *Ralstonia solanacearum*, causes yellowing foliage and wilting and death has been reported in China and India (Liang and Chen, 1982). Other serious recorded diseases include serious stem cankers and dieback caused by *Phomopsis casuarinae* (Anamorphic Diaporthe), and *Botryosphaeria ribis* and pink disease (*Corticium salmonicolor*) (Pongpanich, Luangviriyasaeng and Dudzinski, 1996). Brown rot caused by *Phellinus noxius* causes tree decline in Taiwan (Chang, 1995).

INVASIVENESS

Casuarina equisetifolia has the potential to become a weed under certain conditions which has been observed in the United States in Hawaii and Florida. It has colonized disturbed native vegetation formations and interfered in the nesting of sea turtles on foreshore dunes (Geary, 1983).

Dalbergia latifolia

Order and Family: Fabales: Fabaceae
Common names: blackwood; Indian rosewood

NATURAL DISTRIBUTION

Dalbergia latifolia is indigenous to south and Southeast Asia. In India it is widely distributed from the sub-Himalayan tract to southern India at altitudes from 0 to 900 m (1350 m in southern India). It is not a gregarious tree and occurs scattered in mixed deciduous forests.

PESTS

Arthropods in indigenous/introduced range

More than 40 species of insects, including defoliators, bark feeders and sap suckers, are known to be associated with living trees of *D. latifolia*. The damage caused by them is insignificant and there is no threat from any of them in the establishment of nurseries or plantations (Beeson, 1941; Mathur and Singh, 1960; Browne, 1968; Troup and Joshi, 1983).

Diseases in indigenous range

Under the humid conditions of Kerala and Karnataka, fungi cause foliage infection of minor importance in nursery seedlings, root suckers and trees in natural stands and plantations (Chiddawar, 1959; Bhat and Hegde, 1991; Sharma, Mohanan and Florence, 1985).

The rust fungi *Uredo sissoo*, *Maravalia achroa* and *M. pterocarpi* have been reported to cause foliage infections in nursery seedlings (Spaulding, 1961; Sharma, Mohanan and Florence, 1985). A *Meliola* sp. causes a sooty mould of seedlings. Root rot of *D. latifolia* caused by *Phellinus gilvus* and *Coriolopsis sanguinaria* are the other minor diseases of the tree, reported from India (Bakshi, 1971, 1976).

Diseases in introduced range

In *D. latifolia*, 13 species of fungi have been reported to cause diseases of nursery seedlings, root suckers and trees in plantations and natural stands. Among them, *Fusarium solani* (Anamorphic *Gibberella*) which causes wilt and dieback of >15-year-old trees, as reported from Indonesia, seems to be economically important (Suharti and Hadi, 1974).

Eucalyptus camaldulensis

Order and Family: Myrtales: Myrtaceae
Common names: river red gum

NATURAL DISTRIBUTION

Eucalyptus camaldulensis is the most widely distributed of all eucalypts. The latitudinal range extends from 12°48' S in the tropical Northern Territory to 38°15' S in cool, temperate Victoria. It occurs throughout inland mainland Australia, typically along water-courses and on flood plains, but occasionally extends to slopes at higher elevations, as in the Mount Lofty Ranges near Adelaide.

PESTS

Arthropods in indigenous range

Insects (e.g. termites and aphids) and rodents may be troublesome in the nursery, and both physical and chemical control measures may be needed.

In Australia, natural stands and plantations of *E. camaldulensis* are affected by many insects and fungi. Leaves are often attacked by leaf chewing insects, particularly of the Chrysomelidae and Curculionidae families (such as *Paropsis* spp., *Chrysophtharta* spp., *Gonipterus* spp., *Oxyops* spp.) (Stone and Bacon, 1995).

Arthropods in introduced range

Where the tree is well adapted outside Australia, it is relatively free from problems. In parts of Africa and Asia, termites affect young trees and must be chemically controlled (Day, Rudgard and Nair, 1994). In Africa, the Australian eucalyptus snout beetle, *Gonipterus scutellatus** (once considered synonymous with *Gonipterus gibberus*), feeds on young shoots but can be controlled biologically. Moribund or newly felled trees may become infested with the Australian stem borer or longicorn beetle, *Phoracantha semipunctata** (Poynton, 1979). The longicorn beetle has caused major damage to plantations of *E. camaldulensis* in parts of North Africa and the Middle East; it is the most important pest of eucalypts in Israel (Mendel, 1987). *E. camaldulensis* was found to be relatively resistant to this pest in southern California, United States, and this was associated with the species drought resistance (Hanks *et al.*, 1995).

Diseases in indigenous range

In the nursery, *E. camaldulensis* is susceptible to a diverse range of fungi causing damping-off, collar rot, and leaf diseases (*Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp., *Cylindrocladium* spp.).

Diseases in introduced range

Disease is most common where the species is planted off-site, or where inappropriate provenances are used, resulting in stressed trees that are more susceptible to disease than healthy ones. Stem cankers and leaf diseases proliferate where rainfall and humidity are much higher than normally encountered in the natural habitat (e.g. in parts of India; Sharma and Mohanan, 1991). In humid regions of Viet Nam and Thailand, many *E. camaldulensis* plants are defoliated by fungi causing severe reductions in growth rate and deformed crowns and stems. Several pathogens are associated with this disease in these countries, with *Cylindrocladium quinqueseptatum*, an important causal agent (ACIAR, 1996). The most susceptible provenances suffer mortality and general decline, but some provenances (e.g. Katherine) are little affected, allowing selection and breeding for resistance to the disease.

In Indonesia, prominent leaf spot symptoms on *E. camaldulensis* have been attributed to an unidentified *Mycosphaerella* sp. (Crous and Alfenas, 1995). *Colletotrichum gloeosporioides* (Anamorphic *Glomerella*) has been found responsible for leaf spot and twig blight diseases of young *E. camaldulensis* plantations in Bangladesh, but was controllable by chemical sprays (Begum, 1995).

Eucalyptus robusta

Order and Family: Myrtales: Myrtaceae
Common names: swamp mahogany

NATURAL DISTRIBUTION

Eucalyptus robusta occurs naturally in Australia, within a narrow coastal strip from southern New South Wales (near Nowra) to coastal southeastern Queensland (northwest of Bundaberg). It is also grows on the offshore islands of North Stradbroke, Moreton and Fraser in southeast Queensland. A disjunct population occurs just north of Yeppoon in coastal, central Queensland.

PESTS

Arthropods in indigenous range

In Australia, *E. robusta* is moderately to highly susceptible to insect attack (Marcar *et al*., 1995). The juvenile foliage is attacked by leaf-blister sawfly (*Phylacteophaga froggatti*) and autumn gum moth (*Mnesampela privata*) while adult foliage is susceptible to lerp (*Cardiaspina* sp.), autumn gum moth, leaf beetle (*Paropsis* spp., *Chrysophtharta* spp.), leaf-blister sawfly, gumtree hoppers (*Eurymela* sp., *Eurymeloides* sp.), scale (*Eriococcus coriaceus*, *Acanthococcus danzigae* (=*E. confusus*) and Christmas beetle (*Anoplognathus* sp.). Older trees under stress by drought are attacked by eucalypt borers (*Phoracantha* spp., *Phoracantha acanthocera* [=*Tryphocaria acanthocera*], *Epithora dorsalis*), and cossid borer (*Endoxyla* spp.). Young trees are susceptible to termites (Ruskin, 1983).

Arthropods in introduced range

The sapwood of sawn timber is prone to attack by *Lyctus* borers (Boland *et al*., 1984). *E. robusta* wood is susceptible to attack by dry-wood termites in Puerto Rico (Longwood, 1961), while the heartwood of *E. robusta* was only slightly resistant to the Formosan subterranean termite, *Coptotermes formosanus*, in Hawaii (Grace, Ewart and Tome, 1996).

The leaf-eating beetle, *Colaspis favosa*, has reportedly caused serious damage to young seedlings and coppice shoots in Florida; older trees are unaffected (Geary, Meskimen and Franklin, 1983). Coleoptera borers (Brazil) and cockchafers (Viet Nam) are also reported pests of *E. robusta* (see review in Fenton, Roper and Watt, 1977).

Susceptibility of *E. robusta* to the Australian eucalyptus snout beetle, *Gonipterus scutellatus** (once considered synonymous with *Gonipterus gibberus*) has caused a cessation of planting of the species in some parts of southern Africa (Fenton, Roper and Watt, 1977; Poynton, 1979).

Diseases in introduced range

Leaf spots on *E. robusta* in the United States (Hawaii), Brazil, Mauritius and Zimbabwe have been attributed to the fungal pathogens *Harknessia hawaiiensis* (Anamorphic *Wuestneia*), *H. insueta* (Anamorphic *Wuestneia*), *Colletrotrichum gloeosporioides* (Anamorphic *Glomerella*) and *Cylindrocladium ovatum* sp. *novus* (see reviews in Fenton, Roper and Watt, 1977; El-Gholl *et al*., 1993). In Australia, leaf spots on *E. robusta* have been attributed to *Readeriella mirabilis* (Anamorphic Ascomycetes) (reviewed in Fenton, Roper and Watt, 1977). In the past, the fungus *Cylindrocladium scoparium* (Anamorphic Calonectria) has caused serious seedling losses in Florida (Durst, 1988), but is now controlled by soil sterilization and sprays. In Puerto Rico, *E. robusta* is susceptible to gummosis and trunk rots caused by *Phaeolus schweinitzii* and *Fomes* sp. (Durst, 1988). Another fungus, *Botryosphaeria ribis*, causes cankers on the trunk (Jacobs, 1981). Susceptibility of *E. robusta* to root rot has also been reported (reviewed in Fenton, Roper and Watt, 1977). In Sao Paulo, Brazil, *E. robusta* has been attacked by the bacterium *Agrobacterium tumefaciens* (formerly *Phytomonas tumifaciens*) (Ruskin, 1983).

Fagus sylvatica

Order and Family: Fagales: Fagaceae
Common names: common beech; European beech

NATURAL DISTRIBUTION

Fagus sylvatica or beech is a deciduous broadleaved tree found in temperate and warm temperate climates of western Eurasia, where it dominates the natural development of forest vegetation (Ellenberg, 1986). The southern limit of the natural distribution of *F. sylvatica* in Europe is from the Pindos Mountains (Greece), the islands of Sicily and Corsica, the Pyrenees, and the Cantabrian Mountains in northern Spain. The western distribution limit is the coast of continental Europe, although beech is indigenous to southern England and southern Scandinavia. The eastern limit is roughly a line from the Baltic Sea to the Black Sea.

PESTS

Beech is less affected by serious diseases than other tree species in western Eurasia. Pathogens can destroy regeneration and individual older beech trees, but no mass destruction on a regional scale has been described (Hartig, 1877; Klimetzek, 1992).

Elateridae larvae, snails (*Agriolima agrestis*, *Arion* spp.), Noctuidae larvae (*Agrotis segetum*) and fungal pathogens of seedlings (*Phytophthora cactorum*, *P. cinnamomi*, *Pythium debaryanum*, *P. ultimum*) cause high mortality (Schwerdtfeger, 1981). Damage in forest nurseries can be mitigated by pesticides.

Arthropods

The larvae of *Cydia fagiglandana* and *Rhynchaenus fagi* can kill 40 percent of beech mast (Veldmann, 1978).

The gall inducing insects *Contarinia fagi* and *Dasyneura fagicola* can destroy buds at bud burst (Schwerdtfeger, 1981). If the terminal bud is injured the tree tends to become forked.

Several insect species (e.g. *Operophtera fagata*, *Ennomos quercinaria*, *Rhynchaenus fagi*, *Dasychira pudibunda*) can completely defoliate beech stands, but as attacks do not occur until well after foliage has developed, the main effect of them is a reduction in annual increment and fruit production, rather than long-term damage (Schwerdtfeger, 1981). Protection from biotic damage can be undertaken using chemical pesticides, but these are only used in nurseries.

Diseases

Germinative capacity can be reduced by infection of beech nuts with the pathogen *Thanatephorus cucumeris* (Dubbel, 1992). Fungal infections and staining of fruits can be prevented by use of nets to harvest beech nuts (Dubbel, 1989; Burschel and Huss, 1987).

Generally the most serious and mortal diseases of beech affect the stem. Beech bark disease is the only serious disease of beech in Europe. This complex disease can be widely observed and appears to be chronic on a local to regional scale. It tends to occur on trees previously subjected to stress due to prolonged drought (or other causes): a minute sap-sucking insect, the felted beech coccus (*Cryptococcus fagisuga*), attacks the tree, followed by infection of the pathogenic fungus *Nectria coccinea*. The combined attack of insect and fungus can result in tree death due to moisture stress. In some cases, the succession of secondary pathogens may include wood-boring insects

(*Xyloterus domesticus*) and *Hylecoetus dermestoides* and, finally, white rot (*Fomes fomentarius*, *Fomitopsis pinicola*, *Polyporus* spp.) (Lunderstadt, 1992; Schwerdtfeger, 1981). Protection against biotic damage can be achieved by the immediate removal, through felling, of infected trees.

Gmelina arborea

Order and Family: Lamiales: Verbenaceae
Common names: candahar; gamhar; gumhar

NATURAL DISTRIBUTION

Gmelina arborea is indigenous to India, Pakistan, Bangladesh, Myanmar, Sri Lanka, Thailand, the Lao People's Democratic Republic, Cambodia, Viet Nam, and Yunnan and Guangxi provinces in China (Troup, 1921; Moldenke, 1977; Greaves, 1981; Gupta, 1993; Luna, 1996). It is found in deciduous forest and moist deciduous forest, but also sometimes occurs in evergreen and *Shorea robusta* forests. It is seldom found above 1200 m altitude in the Himalayan region (Troup, 1921), but it has been observed above 1500 m in the Sri Lankan moist forests (Greaves, 1981).

PESTS

Severe pest and disease problems are frequent in plantations within the natural distribution of *G. arborea* and have even led to the failure of plantations (Homfray, 1937; Allsop, 1945).

Arthropods in indigenous range

Insect pests that are common in *G. arborea* plantations within the natural distribution area are stem borers, leaf defoliators and leaf or shoot cutters. Stem borers include *Dihammus cervinus* (Beeson, 1961) in India and Myanmar; leaf defoliators include larvae of *Calopepla leayana* in Assam, Bengal and Myanmar (Ahmed and Sen, 1990), and nymphs and adults of *Tingis beesoni* in India and Myanmar (Greaves, 1981). Dieback is caused by shoot cutters such as the larvae of *Alcidodes ludificator* (=*gmelinae*) in Assam, Bengal and Myanmar (Greaves, 1981).

Arthropods in introduced range

Although *G. arborea* planted outside its natural range suffers similar pest problems, on the whole these are less serious. Leaf defoliators on seedlings and in mature stands are very common. In Nigeria alone, Roberts (1969) noted that defoliators such as *Apophylia nigricollis*, *Zonocerus variegates* and *Achaea lienardi* are common in plantations. In the Philippines, defoliators such as *Chrysodeixis chalcites*, *Acherontia lachesis*, *Ozola minor* and *Attacus* spp. are common in nurseries and plantations (Lapis and Bautista, 1977; Lapis and Genil, 1979). In Latin America, leaf-cutting ants (*Atta* spp.) are a major problem for stem quality and growth of plantations (Greaves, 1981). In Malaysia, a beehole borer, *Duomitus ceramicus* is a damaging insect pest (Ahmad Said, 1989). Chey (1996) reported that *Coptotermes curvignathus*, a termite pest that severely damages *G. arborea* plantations in Malaysia, can be controlled by the application of the termiticide chlorpyrifos. See also records of other insect pests in Browne (1968).

Diseases in indigenous range

Fungal attacks are less prevalent, but can cause damage to *G. arborea* stands. Bagchee (1952) recorded a leaf spot leading to defoliation caused by a *Gnomonia* sp. A species of *Poria* attacks *G. arborea* in India and Bangladesh during waterlogging (Bagchee, 1952, 1953). A powdery mildew, *Phyllactinia guttata*, attacks leaves but does not seriously affect the whole tree.

Diseases in introduced range

Outside the natural distribution of *G. arborea*, fungal diseases are mainly root diseases found in Africa and Latin America. Root diseases of nursery seedlings are normally caused by *Gibberella fujikuroi* in Gambia and *Athelia rolfsii* in Sierra Leone, Gambia and Nigeria (Gibson, 1975). *Thanatephorus cucumeris*, *Chaetophoma* sp. (Anamorphic Ascomycetes), *Polyporus* sp. and *Armillaria mellea** are also causal agents of root diseases in Nigeria and Cote d'Ivoire (Gibson, 1975). In Amazonia, *Ceratocystis fimbriata*, which is an important pathogen of rubber, mango, coffee and cocoa, also infected *G. arborea*; the vectors of the fungus are insects of the genera *Scolytus* and *Platypus* (Muchovej, Albuquerque and Ribeiro, 1978). In Malaysia, diseases such as leaf spot, collar-rot and wilt have been identified, caused respectively by the fungi *Colletotrichum gloeosporioides* (Anamorphic *Glomerella*), *Thanatephorus cucumeris* (Anamorphic *Ceratobasidium*) and *Pythium* spp. Treatments to overcome these diseases are prescribed by Maziah and Norani (1988). Stem rot and anthracnose are common seedling diseases in Malaysia, although these can be controlled (Lee and Goh, 1989).

Juglans nigra

Order and Family: Juglandales: Juglandaceae
Common names: black walnut

NATURAL DISTRIBUTION

The natural range of *Juglans nigra* covers much of the eastern United States and into Lower Canada. Baker (1921) divided the range of *J. nigra* into botanical, primary commercial and secondary commercial ranges.

PESTS

Arthropods in indigenous range

A range of insects occur on *J. nigra* in its natural range; some cause quality loss through retarding form and others are recognized as important causes of growth loss. Schlesinger and Funk (1977) consider the major threats to growing *J. nigra* in the United States are walnut caterpillar, bud borers, casebearers and anthracnose.

Walnut caterpillar (*Datana integerrima*) is regarded as the most destructive leaf-feeding insect that occurs on *J. nigra* (Linit and Stamps, 1997), but the damage is considered minor as most feeding occurs late in the growing season (Marshall, 1989).

Fall webworm (*Hyphantria cunea*) is another common *J. nigra* defoliator that forms a web over branches about mid-July (Weber, 1988). As with walnut caterpillar, damage is usually at the end of the growing season (Marshall, 1989).

Walnut shoot moth (*Acrobasis demotella*) is considered the most destructive shoot borer on *J. nigra* (Linit and Stamps, 1997). Females deposit single eggs on the underside of leaves in early summer; these overwinter at the base of buds and emerge to bore into the elongating shoot at bud swell, destroying the shoot. Rink *et al*. (1991) concluded that *Acrobasis* infestation appeared to be a problem primarily on young trees <2.5 m in height, but there was no evidence for genetic resistance to *Acrobasis* infestation in *J. nigra*.

Ambrosia beetles (*Xylosandrus germanus*) develop galleries in the stem and the larvae feed on fungi growing in the gallery. They usually attack slower growing trees less than 3 m tall (van Sambeek and Schlesinger, 1988).

Black walnut curculio (*Conotrachelus retentus*) develops in the nuts of *J. nigra*. The female deposits an egg within the developing nut and as the larva feeds, the nut is dropped prematurely; its abundance is determined by the availability of nuts during the previous year (Linit and Stamps, 1997).

Diseases in indigenous range

Walnut anthracnose (*Gnomonia leptostyla*) is a fungus which causes premature leaf drop, resulting in growth loss and reduction in quantity and quality of nut crops. Wet weather in which the foliage is covered with moisture for prolonged periods makes the disease more severe (Kessler, 1988). Field and glasshouse trials have shown that fertilization enhanced resistance to walnut anthracnose and delayed premature defoliation (Neely, 1981, 1986). Incidence of walnut anthracnose can also vary with seed source (Funk *et al*., 1983), while interactions occur with selecting for growth and/or resistance.

Cankers are caused by fungi that enter the tree through unprotected wounds, small injuries, or leaf scars. Cankers lasting more than a year (perennial or target cankers) are caused by a *Nectria* fungus (*Neonectria galligena*) (Kessler, 1988). Studies of canker incidence and effect found that tree growth rate was 30 percent less for trees with cankers than for healthy trees (Thomas and Hart, 1986), and that soil texture, rooting depth and drainage features were not significant to disease incidence but some surface geology and topographic features were (Thomas and Hart, 1986).

Walnut black line disease, caused by the walnut strain of the cherry leaf roll nepovirus (CLRV), causes fatal necrosis of the graft union between susceptible, infected scions of Persian walnut (*Juglans regia*) and hypersensitive, resistant rootstocks. *J. regia* is tolerant whereas *J. hindsii* (a hybrid of *J. hindsii* and *J. regia*) is hypersensitive. Dosba *et al*. (1990) report CLRV was found in many cultivars of *J. regia* and always detected in *J. regia*/*J. nigra* showing black line, but the distribution of the virus was irregular; virus progression inside the tree was slow. Seed and pollen transmission were also demonstrated. It was concluded that the rootstocks belonging to *J. nigra*, *J. major*, *J. sieboldiana*, nom. illeg. and various interspecific hybrids did not multiply the virus.

Diseases in introduced range

Bacterial blight is considered one of the most serious diseases affecting the genus *Juglans* in Italy. Artificial inoculations with *Xanthomonas arboricola* pv. *juglandis* were performed in an open field nursery by spraying seedlings of *Juglans* species and hybrids. None of the tested bacterial strains multiplied in the leaves of *J. nigra*. This confirms the results obtained in field tests. *J. regia* was the most susceptible among the walnut species tested (Belisario *et al*., 1999).

Belisario and Corazza (1996) reported from Italy that *Corticium rolfsii* was isolated from diseased walnuts (*J. regia*) and *J. nigra* seedlings in the field in 1995. *J. nigra* seedlings were more susceptible than *J. regia* seedlings. This was the first report of *C. rolfsii* on *J. regia* and *J. hindsii* and its first record on *Juglans* in Europe.

Belisario (1996) report that blight (caused by *Xanthomonas arboricola* pv. *juglandis*) was the major disease of *J. regia* in Italy, causing severe damage in both nurseries and plantations. Anthracnose (caused by *Gnomonia leptostyla*) was damaging only in plantations, where it affected both walnut species. Copper treatments were effective against the two diseases. Other diseases were present but most of these were opportunistic pathogens and infections could be prevented by growing walnut trees under suitable cultural and environmental conditions (Belisario, 1996). Luisi and Campanile (1993) also implicated environmental factors, suggesting that *Sphaeropsis camarosporium* caused the most severe symptoms in areas with low soil fertility, with prolonged spring and summer drought, and in neglected plantations.

Khaya ivorensis

Order and Family: Sapindales: Meliaceae
Common names: African mahogany

NATURAL DISTRIBUTION

Khaya ivorensis occurs in West Africa mostly in Cote d'Ivoire, Ghana, Togo, Benin and Nigeria.

PESTS

Arthropods in indigenous range

The larvae of *Hypsipyla robusta** feed on the soft tissue inside the terminal stem. In heavy infestations as many as 20 to 40 wounds may occur on a stem resulting in a heavy exudation. This species also lays eggs on seeds and larvae bores through seeds. Mature larvae move from fruit to fruit feeding. Trees are attacked in their second or third year. Generally shoot borer attack weakens the tree and predisposes it to attack by other insects and fungi. With repeated infestations mortality can occur. Economic loss is usually due to reduced height growth and poorer forms of infested trees. Attempts to control *H. robusta* with systematic insecticides including brushing Bidrin on affected parts have been only partially successful. Silvicultural control methods are used to increase shade and isolate infested trees.

Catopyla dysorphanea lays eggs on fruit and larvae at first feed within individual seeds then move from fruit to fruit. *Xylosandrus compactus*, *Xyleborus perforans*, *X. semiopacus*, and *X. sharpi* attack temporarily stressed or injured trees but also attacks transplants that have yet to recover from transplant shock.

Gyroptera robertsi attacks mainly old trees. *Cledus obesus* has larvae which tunnel in the stem branch axils causing stem to swell at the point of infestation. *Udinia faraquarsoni* sucks sap from the abaxial portion of leaves and *Pseudophacopteron zimmerani* produces numerous galls (3 to 5 mm in diameter) on *K. ivorensis* (Wagner, Atuahene and Cobbinah, 1991).

Diseases in indigenous range

Fungus diseases include *Phellinus noxius*, which attacks the roots, and *Uredo tesoensis*, which attack the leaves.

Lovoa trichilioides

Order and Family: Sapindales: Meliaceae
Common names: African walnut

NATURAL DISTRIBUTION

L. trichioides is naturally distributed in the Guinea-Congolian region, from 10° N to 10° S (Hall and Swaine, 1976). It is one of the main timber species in the Congo and exploitation rates are high (Oldfield, Lusty and MacKinven, 1998).

PESTS

Very little is recorded regarding pests and diseases of *L. trichilioides*. It is considered less susceptible to tree borers and other insects than others in this genus, and *Catopyla dysorphnaea*, a minor stem borer of maize, has been recorded on the fruits and seeds of *L. trichilioides* (Wagner, Atuahene and Cobbinah, 1991).

Paulownia tomentosa

Order and Family: Scrophulariales: Scrophulariaceae
Common names: paulownia; princess tree

NATURAL DISTRIBUTION

Paulownia tomentosa is native to China, and is widely distributed in central and northern regions. It is one of the most important tree species in China and currently there are about 1.1 billion Paulownia trees planted throughout the country. It occurs in Japan and South Korea, but some Japanese taxonomists believe that these are naturalized populations resulting from past introduction and cultivation of this species in these countries. *P. tomentosa* naturally occurs in deciduous and mixed forest species, and to a lesser extent in secondary forest.

PESTS

Arthropods in indigenous range

The main pest found on *P. tomentosa* is *Eumeta variegata*, and Yang and Li (1982) discuss methods used to control this defoliator. *E. variegata* occurs throughout the distribution range of *P. tomentosa*; it develops one generation in northern China and two generations in southern China. Seedling stock is the major source of spread of this pest (Yang, Zhou and Gao, 1975).

Diseases in indigenous range

In plantations this species is susceptible to Paulownia witches' broom disease, which is caused by a phytoplasma (previously described as a mycoplasma-like organism). This disease may be identified by distinctive yellow broom-like shoots, which die back in the autumn. It is commonly found in seedling stocks and young trees (3 to 6 years old), and may greatly influence their growth. It may also occur in adult trees, but has little effect on their growth. In its natural environment the disease is spread by *Halymorpha picus*. Infected roots and seedling stock aid the spread of this disease, yet seeds obtained from infected trees may grow disease-free. The effects of Paulownia witches' broom disease vary depending on the *Paulownia* species. Selecting clones with good resistance and using suckers free of the disease will reduce spread of the disease.

Anthracnose disease is a major disease in saplings that injures leaves, petolies and shoots, and causes early leaf drop. *P. tomentosa* also suffers damping-off disease caused by *Thanatephorus cucumeris* (Anamorphic Ceratobasidium) and *Fusarium* spp. (Anamorphic *Gibberella*) (Zhu *et al*., 1986). Other diseases include the nematode *Meloidogyne marioni*, which infects the roots of seedlings and results in mortality, and the fungus *Sphaceloma tsugii* (Anamorphic Elsinöe), which commonly damages seedling shoots and causes dieback. Both diseases have a common occurrence throughout the distribution range of *P. tomentosa*.

Picea sitchensis

Order and Family: Pinales: Pinaceae
Common names: sitka spruce

NATURAL DISTRIBUTION

Picea sitchensis is an ecologically important species of the north temperate coastal rain forest of western North America. The natural range of *P. sitchensis* spans a narrow strip on the north Pacific coast of North America, extending for 2 900 km from 61° N in south-central Alaska to 39° N in northern California. Throughout this tremendous north-south range, *P. sitchensis* is a coastal species. While its natural range is not extensive and the species' economic importance ranks far below that of other western conifers, it is a keystone species in some of the most productive ecosystems of North America, particularly in the Queen Charlotte Islands of British Columbia (Peterson *et al*., 1997).

PESTS

Arthropods in indigenous range

By far the most serious insect pest of *P. sitchensis* in North America is the white pine weevil (*Pissodes strobi*), particularly in the southern part of the range and on warmer sites inland from the coast (Martineau, 1984; Warkentin *et al*., 1992; Alfaro, 1994). Adults overwinter in the litter and emerge in the spring to mate and lay eggs in feeding punctures made on the tree's leader. The larvae hatch two weeks later and tunnel down the inner bark of the shoot, killing the leader and seriously affecting tree form and reducing merchantability (Alfaro, 1982, 1989). The risk and impact of damage is so great that annual *P. sitchensis* planting in British Columbia is limited to about 2 million seedlings, established only on cooler sites. Putative resistance of individual trees is a complex trait involving phenology, leader length and morphology, resin canal density and chemical components, and appears to be genetically inherited as is the level of damage sustained by trees following attack.

Arthropods in introduced range

Outside its natural range, *P. sitchensis* has played an important role in plantation forestry, particularly in northern Europe (Hermann, 1987).

Except in high-value seed orchards and nurseries, the economic impact of insect pests other than *P. strobi* in North America is low although the number of insect species with potential to do damage is rather high. In Great Britain, the diversity and impact of insect pests have been limited by the relatively short period since introduction and the area planted (Evans, 1987). In the United Kingdom, the green spruce aphid (*Elatobium abietinum*) is a sap-sucking insect feeding on many species of spruce, although *P. sitchensis* has the least resistance owing to low concentrations of volatile plant compounds (Nichols, 1987). Outbreaks occur periodically in both North America and Britain, particularly when mild weather results in favourable overwintering conditions (Powell and Parry, 1976; Straw, 1995), and defoliation can result in serious growth losses and up to 10 percent mortality (e.g. Seaby and Mowat, 1993).

Diseases in indigenous range

While many pathogens can attack *P. sitchensis* at various stages of its life cycle, only a small number of decay fungi cause serious commercial damage. In both North America and Europe, *P. sitchensis* is susceptible to *Heterobasidion annosum* causing butt rot (Morrison, Larock and Waters, 1986), and can result in significant loss of yield and quality in plantations (Pratt, 1979a, 1979b). *P. sitchensis* is also host to Armillaria root rot*, but usually only young trees are killed (Morrison, 1981). *Phellinus weirii* causes butt decay in older trees, but only young trees are likely to be killed (Nelson and Sturrock, 1993).

Pinus oocarpa

Order and Family: Pinales: Pinaceae
Common names: ocote pine; ocote chino; oocarpa pine

NATURAL DISTRIBUTION

Pinus oocarpa grows naturally in Mexico, Guatemala, Belize, Honduras, El Salvador and Nicaragua. Most of the trees are concentrated on the southwestern (Pacific) half of the axis running through these six states. In Mexico the tree grows in abundance on the lower slopes of the sierras of the western and southern parts of the country. It is plentiful in the mountains of southern Guatemala and central Honduras, northern El Salvador and northwestern Nicaragua.

PESTS

Arthropods in indigenous range

Mexican pine bark beetles, *Dendroctonus mexicanus*, can destroy a substantial number of trees. Other Central American insects that can cause damage to trees are *Rhyacionia* spp. (pine tip moths), *Pissodes* spp. (shoot weevils), defoliators (Tortricidae), a pine bark beetle *Dendroctonus frontalis**, and cone weevils (Perry, 1991).

Diseases in indigenous range

Seedlings are prone to damping off while growing in the nursery.

Pinus radiata

Order and Family: Pinales: Pinaceae
Common names: radiata pine

NATURAL DISTRIBUTION

Pinus radiata occurs naturally in just five discrete populations off the coast of the Baja California Peninsula (Mexico). The location and habitats of the mainland populations have been described by Lindsay (1932), Roy (1966) and Forde (1964) and those for the islands by Libby, Bannister and Linhart (1968) (see also Moran, 1996) specifically for Guadalupe Island). The total extent of natural forest, prior to European impacts, was slightly under 10 000 ha, of which about 5 300 ha remain (Burdon, 2000). All natural habitats represent a special and highly localized variant of the dry to mesic Mediterranean climate (rainfall generally 700 mm or less), caused by a cold ocean current; summer temperatures are mild, and sea fogs during the essentially rainless summer months produce a crucial amount of occult precipitation in the form of fog drip. Nowhere do natural stands extend beyond 8 km inland. Altitude ranges from sea level to 420 m on the mainland, and from 300 to 1 200 m in the more southerly island populations. Geology and soils are highly variable, overall and within the Monterey population. Within its range, *P. radiata* is generally the sole high-forest species.

PESTS

The species has become naturalized in several countries, notably New Zealand, Chile, Australia and South Africa, often regenerating naturally within plantations and often invading surrounding land.

Damage agents, in the forms of fungal pathogens, insect pests and environmental factors, are inevitably important, given the attractions of growing the species to the limits of its site tolerances (Scott, 1960; Burdon, 2000).

Arthropods in indigenous range

Various insect pests are present in native stands (Ohmart, 1982), but have historically been in ecological balance with the *P. radiata*. Various scolytid beetles, and some other insects, have evidently become significant primarily for their role as vectors for the introduced pitch canker (*Gibberella circinata*).

Arthropods in introduced range

The woodwasp *Sirex noctilio** can kill trees very quickly by attacking the boles. Spectacular tree mortality in New Zealand in 1946–1949, but that did little real harm and sirex is now unimportant because of effective biological control. Sirex has since been introduced into many other countries where it is of major concern incuding Australia, Argentina, Brazil, Canada, Chile, South Africa, United States and Uruguay.

The bark beetle *Ips grandicollis* is a significant pest in Australia. The European pine shoot moth, *Rhyacionia buoliana* has long caused varying amounts of leader damage in plantings in Europe, and can limit the use of *P. radiata*. It has spread to Argentina and then to Chile, where it is a major pest. The processionary caterpillar, *Thaumetopoea pityocampa**, is a significant defoliator in warmer parts of Europe, where it limits the use of *P. radiata*. Another defoliator is the pine emperor moth, *Imbrasia cytherea*, which can be troublesome in South Africa. The pine woolly aphid, *Pineus pini*, is a minor pest in many parts, but has recently caused concern in South Africa. Other insect pests of *P. radiata* have been covered by Rawlings (1955), Scott (1960) and Lavery (1986).

Diseases in indigenous range

Several fungal pathogens are known to limit the sites on which the species can be grown successfully (see Offord, 1964). Fungal pathogens are perhaps more important than insect pests because they tend to affect trees more on the moister sites that are potentially much more productive. These include *Mycosphaerella pini**, which causes needle cast although it can often be controlled by aerial spraying of copper fungicide, and western gall rust, *Endocronartium harknessii* (syn. *Peridermium harknessii*), which causes galls that often develop into serious stem cankers. These two pathogens have limited where *P. radiata* can be grown in wetter conditions north of the species' natural range on the California coast. Fortunately, western gall rust has not reached plantations outside North America, where its potential impacts are conjectural.

Sphaeropsis sapinea (syn. *Diplodia pinea*) is often the immediate cause of failure in summer-rainfall areas characterized by damp heat. It usually causes shoot dieback and can attack both wounds and uninjured shoots. It also affects drought-stressed trees, causing the condition that is called 'autumn brown top' in Australia.

Pitch canker, caused by *Gibberella circinata* is a disease that has recently reached the native populations of mainland California (Storer *et al*., 1997). It causes shoot dieback resembling that caused by *S. sapinea*, but can readily affect much larger limbs, including the bole. Its final impact is unclear, but it is seen as a very serious threat to the native stands, *P. radiata* being one of the most susceptible pines (see also Dick, 1998; Hodge and Dvorak, 2000).

The potential impact of pitch canker in exotic stands, where it is not yet present, is unknown; most of its Californian vectors are not present elsewhere, but its ready transmission by seed is a concern.

Diseases in introduced range

Root-rot fungi of the genus *Armillaria*, notably *A. mellea**, are locally important. In New Zealand they can cause severe losses where *P. radiata* has replaced freshly-cut native forest and may become progressively more troublesome after the first rotation planted on unforested land. The impact can be much increased by the presence of significant *Mycosphaerella* infection.

The root pathogen *Phytophthora cinnamomi* is locally important where there is seasonal waterlogging, especially in Western Australia. The needle-cast fungus, *Naemacyclus minor* (syn. *Cyclaneusma minus*), is notable for its almost ubiquitous occurrence, rather than acute impacts. Various other pathogens have been reported; some being locally serious (see Rawlings, 1955; Poynton, 1960; Lavery, 1986; Burdon, 2000).

INVASIVENESS

Its invasiveness can sometimes lead to bonus crops of timber, but often leads to the production of unusable trees. It can invade plant communities of considerable conservation value, and in the course of that can reduce catchment water yields. On the other hand, *P. radiata* can often act as an effective nurse crop for re-establishment of natural vegetation. There can be considerable impacts on fauna, some adverse, but some surprisingly favourable (Burdon, 2000).

Populus nigra

Order and Family: Salicales: Salicaceae
Common names: black poplar

NATURAL DISTRIBUTION

The natural distribution of *Populus nigra* covers a large range from central and southern Europe (including the United Kingdom) to Western and Central Asia reaching the Jenisse River in Siberia.

PESTS

Arthropods in indigenous range

Poplars are hosts to a large number of insect species, but only a few of these are of any importance. The most important are: the goat moth (*Cossus cossus*); the large longhorn beetle (*Saperda carcharias*) and the weevil (*Cryptorhynchus lapathi*). *Paranthrene tabaniformis* attacks young trees. Larval damage of wood by boring is caused by all these pests. *C. cossus* and *S. carcharias* attack old trees, whereas *C. lapathi* only damages young trees. The woolly poplar aphid (*Phloeomyzus passerinii*) can also damage trees; only genotypes of *P. nigra* collected in xeric and warm habitats are resistant (Allegro and Cagelli, 1996).

Defoliating beetle pests of *P.* x *canadensis* include the large poplar-leaf beetle (*Chrysomela populi*) and larvae of the white satin moth (*Leucoma salicis*). Larvae of the poplar shoot borer (*Gypsonoma aceriana*) may cause failure of the leading shoots by boring them. Occasionally other insect pests such as *Operophtera brumata*, *Leucoptera sinuella*, *Lymantria dispar** and *Clostera* spp. can cause damage. The minor pest, woolly poplar aphid, *Phloeomyzus passerinii*, can be controlled by selection of resistant clones (Giorcelli and Allegro, 1998).

Arthropods in introduced range

P. nigra is naturalized in North America (USDA, 1999) and in South America (Jobling, 1990) where the cv. Chile, remarkable for its almost evergreen habit, is found (Van Kraayenoord, 1959). Larvae of a sesiid (*Paranthrene dollii*) in the United States and a hepialid (*Phassus excrescens*) in Japan are reported to bore in trunks and branches. *Hyphantria cunea* can be a significant defoliator in North America (Allegro and Picco, 1992) but can be controlled by *Bacillus thuringiensis*. In South America ants of the leaf-cutting genera *Atta* and *Acromyrmex* are harmful to poplars, cutting and consuming leaves.

Diseases in indigenous range

The fungal pathogen *Drepanopeziza populorum* and several species of *Melampsora* (for example, *Melampsora laricis-populina*) can cause premature defoliation of trees. *Venturia populina* attacks leaves and young shoots causing complete defoliation and deformation of the shoot/branch early in spring (Vietto and Giorcelli, 1996).

Serious attacks of *Cryptodiaporthe populea* cause cankering and dieback especially in nurseries or on the young sapling after transplantation (Gojkovic and Avramovic, 1985; Anselmi, 1986). *Davidiella populorum* causes leaf spot and cankers.

Fungal disease can be controlled spraying fungicides, or by selecting varieties or clones which are tolerant or resistant (Giorcelli and Vietto, 1995, 1998).

Pseudotsuga menziesii

Order and Family: Pinales: Pinaceae
Common names: Douglas fir

NATURAL DISTRIBUTION

The latitudinal range of *Pseudotsuga menziesii* is the greatest of any commercial conifer of western North America – from 19 to 55 °N latitude. The range of var. *menziesii* extends from central British Columbia south along the Pacific Coast Ranges for about 2 200 km into California (near 35 °N latitude); the range of var. *glauca* stretches from central British Columbia along the Rocky Mountains into the mountains of central Mexico over a distance of nearly 4 500 km (Hermann and Lavender, 1990).

PESTS

Arthropods in indigenous range

The Douglas-fir tussock moth (*Orgyia pseudotsugata*) and the spruce budworm (*Choristoneura fumiferana*) are the most important destructive insects of *P. menziesii* in its native range. Both insects attack trees of all ages at periodic intervals throughout the range of interior population, often resulting in severe defoliation of stands. The Douglas-fir beetle (*Dendroctonus pseudotsugae*) is a destructive insect pest in old-growth stands (Hermann and Lavender, 1990). The Douglas-fir woolly aphid (*Gilletteella cooleyi*) can severely check the growth of some provenances on some sites (Savill, 1991).

The cones and seeds are host to a number of destructive pests (Furniss and Carolin, 1977; Hedlin *et al*., 1980). The Douglas-fir seed chalcid (*Megastigmus spermotrophus*) matures in the developing seed and gives no external sign of its presence. Larvae of the Douglas-fir cone moth (*Barbara colfaxiana*) and the fir cone worm (*Dioryctria abietivorella*) bore through the developing cones. The Douglas-fir cone gall midge (*Contarinia oregonensis*) and the cone scale midge (*C. washingtonensis*) destroy some seed but prevent harvest of many more by causing galls that prevent normal opening of cones.

The European strawberry root weevil (*Otiorhynchus ovatus*) and cranberry girdler (*Chrysoteuchia topiaria*) may cause significant damage to seedlings in nurseries (Hermann and Lavender, 1990).

Diseases in indigenous range

P. menziesii is host to hundreds of fungi, but relatively few of these cause serious problems. Various species of *Pythium*, *Rhizoctonia*, *Phytophthora*, *Fusarium*, and *Botrytis* may cause signficant losses of seedlings in nurseries (Peterson and Smith, 1975; Sutherland and van Eerden, 1980), whereas *Rhizina undulata*, shoestring root rot (*Armillaria mellea**), and laminated root rot (*Phellinus weirii*) have caused significant damage in plantations. The latter two fungi represent a serious threat to management of young stands of *P. menziesii*, especially west of the Cascade Mountains. Trees die or are so weakened that they are blown over. Effective control measures are not available.

Of the many heart rot fungi (over 300), the most damaging and widespread is red ring rot (*Porodaedalea pini*). Knots and scars resulting from fire, lightning, and falling trees are the main routes of infection. Losses from this heart rot far exceed those from any other decay. Other heart rot fungi in the Pacific Northwest are *Fomitopsis* *officinalis* (=*Laricifomes officinalis*), *F. cajanderi* and *Phaeolus schweinitzii* (Hepting, 1971). In the southwest United States, *Echinodontium tinctorium*, *Fomitopsis cajanderi*, and *F. pinicola* are important.

Among several needle diseases, the most conspicuous is a needlecast caused by *Rhabdocline pseudotsugae*. It is mainly a disease of younger trees, reaching damaging proportions only after prolonged periods of rain while the new needles are appearing (Hermann and Lavender, 1990). The Swiss needle-cast fungus (*Phaeocryptopus gaeumannii*) also occurs on *P. menziesii* throughout its natural range, usually causing little damage.

Diseases in indigenous range

Where Douglas fir has been planted elsewhere (eastern United States, Europe and New Zealand), significant reductions in growth have been associated with *Phaeocryptopus gaeumannii*. Studies in New Zealand have indicated that the losses are linked to a variety of influences, including insect defoliators, and are not solely attributable to the needle-cast fungus (Miller and Knowles, 1994).

Parasitic plants

A mistletoe species, *Arceuthobium douglasii*, is a significant parasite throughout most of the natural range of *P. menziesii* (Hawksworth and Wiens, 1972).

Shorea macrophylla

Order and Family: Malvales: Dipterocarpaceae

NATURAL DISTRIBUTION

Shorea macrophylla is indigenous to Borneo, and is especially widespread in west and central Sarawak, Kapuas valley, Tidung and Burau. It is commonly found in lowland tropical rain forest, and seldom occurs above 600 m in altitude (Ashton, 1964). In Brunei, this species is confined to damp clay soils near rivers and streams and has less favourable growth in hillsides, ridge tops or upper slopes (Rasip and Lokmal, 1994). *Shorea macrophylla* is rarely gregarious and is often scattered at a low density. This climax species is commonly found in riparian forests and also establishes well in canopy gaps.

PESTS

Diseases in indigenous range

Seedlings of *S. macrophylla* are affected by damping-off in the nursery resulting in decay and death. This is caused by fungi which occur naturally in the soil such as *Fusarium* spp. and *Pythium* spp. (Chin, 1995). This species also suffers from wilt, the control of which is discussed by Chin (1995). Heart rot is another form of decay whereby the heartwood loses its strength and may crumble.

A deformed stem is likely to develop in the species if the apical shoot is destroyed either by insects, climbers, or heat stress, as is found in other dipterocarps such as *S. platyclados* (Ang and Maruyama, 1995).

Swietenia macrophylla

Order and Family: Sapindales: Meliaceae
Common names: big-leaved mahogany; broad-leaved mahogany

NATURAL DISTRIBUTION

The genus *Swietenia* has a natural distribution from 20 °N to 18 °S in tropical America. *Swietenia macrophylla* is the most widely distributed species occurring from the Atlantic regions of southeast Mexico, through Central America, northern South America and in an arc across the southern Amazon Basin, in Bolivia and Brazil (Lamb, 1966; Styles, 1981).

PESTS

Arthropods in indigenous range

Shoot borers, *Hypsipyla* spp., principally *H. grandella**, are the major limitation to artificial establishment of mahogany in Central and South America (Martorell, 1943; Ramirez-Sanchez, 1964; Bauer, 1987). In Colombia, various silvicultural and agroforestry trials show no consistent successful methods of shoot borer control (Vega Gonzalez, 1987). However, trials established in many parts of Central America proved that shoot borer damage can be partially controlled by cultural methods (Newton, Leakey and Mesen, 1992). A combination of silvicultural, biological and chemical control was proposed by Newton, Leakey and Mesen (1992); and production of resistant plants through selection has been suggested as the most effective method (Grijpma, 1976; Newton, Leakey and Mesen, 1992). The use of slow release/systemic insecticides has also shown promising results (Chaplin 1993). See Newton *et al*. (1993) and Floyd and Hauxwell (2001) for reviews.

Arthropods in introduced range

*Hypsipyla robusta** causes serious damage in nurseries and plantations in the Solomon Islands (Chaplin, 1993) and other areas. In Fiji, ambrosia beetles (*Crossotarsus externedentatus*, *Platypus gerstaeckeri*) may attack living trees and cause variable, sometimes major, levels of pinhole damage. The small holes and associated staining may considerably reduce the value of the timber for decorative uses (Oliver, 1992). An ambrosia beetle (*Xylosandrus compactus*) has also been observed to cause damage in young stands in Puerto Rico (Bauer, 1987). Termites are also potentially a major damage agent in mahogany plantings in Fiji.

Tectona grandis

Order and Family: Lamiales: Verbenaceae
Common names: teak

NATURAL DISTRIBUTION

Tectona grandis is the principal timber tree of peninsular India, Myanmar, Indonesia and Thailand and one of the most valuable timbers in the world. The reputation of teak timber is due to its matchless combination of qualities such as: termite, fungus and weathering resistance; lightness with strength; attractiveness; workability; and seasoning capacity without splitting, cracking, warping or materially altering shape (Kadambi, 1972). *Tectona grandis* is indigenous to south and Southeast Asia. It grows naturally between latitudes of 9° N to 25°30' N in most of peninsular India, large areas of Myanmar, and parts of the Lao People's Democratic Republic and Thailand (White, 1991).

T. grandis has been widely planted both within and beyond its natural range. In Africa, it is a major exotic species planted for sawlogs. It is widespread in Central and South America and in the Pacific. Long established plantations now extend from 28 °N to 18 °S (Rao, 1997). Locations in which *T. grandis* occurs include Southeast Asia, the Pacific, East Africa, West Africa, South Africa, the Carribbean Islands, South America, and Central America (Tewari, 1992).

PESTS

Arthropods in indigenous range

Over 180 species of insects are reported to be associated with teak (Mathur, 1960; Mathur and Singh, 1960). Most of them are minor pests. Those which cause serious damage include white grubs in nurseries, sapling borers in young plantations, trunk borers in older plantations and two species of defoliators (Beeson, 1941; Sen Sarma and Thapa, 1981; Day, Rudgard and Nair, 1994).

In nurseries, white grubs (*Holotrichia* spp.) eat the seedling roots causing wilting and subsequent death. White grubs can be controlled by treating the nursery beds with systemic soil insecticides (Oka and Vaishampayan, 1981; Varma, 1991).

The sapling borer (*Sahyadrassus malabaricus*) is a problem in young plantations, with dense weed growth. It can be managed through regular pest surveillance and spot application of selected insecticides (Nair, 1987).

The defoliator (*Hyblaea puera*) and the skeletonizer (*Paliga machoeralis*, *P. damastesalis*) are recognized as serious pests (Beeson, 1941; Nair, 1988). In young plantations in Kerala, India the teak defoliator causes repeated severe defoliation in the early part of the growth season of a loss of up to 44 percent of the potential volume increment. The skeletonizer on the other hand causes defoliation later in the season and has no significant impact (Nair *et al*., 1996). Although biological control methods using native parasites and silvicultural practices were recommended in the past (Beeson, 1941; Mathur, 1960), this is not currently practiced. Current emphasis is on the use of a naturally-occurring nuclear polyhedrosis virus (NPV) for control of the teak defoliator (Sudheendrakumar, Ali and Varma, 1988; Nair *et al*., 1997).

The beehole borer (*Xyleutes ceramicus*) is a serious pest in Myanmar and Thailand (Beeson, 1941), which also attacks *Gmelina arborea*. It riddles the tree trunk with borer holes severely degrading the quality of wood (Beeson, 1921, 1941; Chalerempongse, Boonthavikoon and Chairuangsirikul, 1990; Hutacharern, 1990). *Cossus cadambae* causes similar problems in the southern states of India, but the incidence is limited to pockets where the trees are subject to repeated lopping (Beeson, 1941; Mathew and Rugmini, 1996).

Arthropods in introduced range

Hyblaea puera occurs widely in the tropics, but curiously there are no significant reports of damage outside its indigenous range.

Diseases in indigenous range

Although diseases are not recognized as major problem in teak, some pathogens are of importance. In nurseries, bacterial wilt caused by *Pseudomonas* spp., leaf spots caused by *Phomopsis* (Anamorphic *Diaporthe*) and leaf rust caused by *Olivea* often cause serious problems (Sharma, Mohanan and Florence, 1985; Balasundaran *et al*., 1995). *Ralstonia solanacearum* causes typical vascular wilt in India, Indonesia, Malaysia and Myanmar while *P. tectonae* is prominent in the Philippines (Gibson, 1975; Sharma, Mohanan and Florence, 1985). Lack of soil drainage and root injury are predisposing factors of bacterial wilt. The leaf spots caused by *Phomopsis tectonae* (Anamorphic *Diaporthe*) in combination with *Colletotrichum gloeosporioides* (Anamorphic *Glomerella*) result in defoliation and death of the seedlings. Rust caused by *Olivea tectonae* results in premature defoliation in nurseries and plantations in India, Pakistan, Sri Lanka, Myanmar, Indonesia and Thailand (Gibson, 1975). In nurseries, rust can be controlled by foliar spray of sulfur-based fungicides. In 1- to 3-year-old plants *Corticium salmonicolor* (pink disease) causes death of terminal shoots in India (Sharma, Mohanan and Florence, 1985) and Indonesia (Gibson, 1975).

In Kerala, India, *T. grandis* is attacked by the trunk borer, *Cossus cadambae*. This results in the infection of the tunnels by the fungus *Pleurostomophora richardsiae* (Anamorphic Ascomycetes) and causes dieback of trees (Sharma, Mohanan and Florence, 1985).

Diseases in introduced range

Several fungi have been reported to cause root rot and decay of standing trees in India, the United Republic of Tanzania, Dahomey, Nigeria and Papua New Guinea, but they are of local and minor importance (Bakshi, 1976; Gibson, 1975; Sharma, Mohanan and Florence, 1985).

Parasitic plants

The mistletoe, *Dendrophthoe falcata*, is a major problem in plantations in almost all the teak-growing countries especially, India, Bangladesh, Indonesia and Trinidad (Murray, 1961; Gibson, 1975; Ghosh, Balasundaran and Ali, 1984). It was found to cause up to 40 percent reduction in annual increment and mortality reaching 9 percent in teak plantations in Kerala, India (Ghosh, Balasundaran and Ali, 1984). Lopping the infested branches before the flowering season is the usual method of management.

Terminalia amazonia

Order and Family: Myrtales: Combretaceae
Common names: nargusta

NATURAL DISTRIBUTION

Terminalia amazonia is found over a very wide area from southern Mexico through Central America and into Brazil and Peru, as well as in Trinidad and Guyana. It is a component of moist to wet tropical forests throughout this region, on a large variety of soil types, including sands and gravels, upland volcanic soils, low fertility clays, and limestone soils. It is generally absent on drier sites within its range. Apparently, plantations to date have been little used and there are no records of the species spreading from its natural range.

PESTS

Arthropods in indigenous range

In general, *T. amazonia* appears to be capable of growing in pure stands with few insect or disease problems, although cautious optimism is warranted in regard to its potential in pure plantations. Ford (1986) reported borer attacks of 4 to 45 percent on various *Terminalia* species in Costa Rica. Larvae of the genus *Cossula* bore underneath the bark and into the xylem and then bore upwards for 25 to 40 cm, making galleries 12 to 14 mm in diameter. Moulaert and Arguedas (1993) reported moderate defoliation damage to plantation trees from *Exophthalmus* spp., a weevil. More seriously, Montagnini *et al*. (1995) observed low survival (66 percent) of planted seedlings due to attacks by leaf-cutting ants.

Diseases in indigenous range

In Costa Rica, Nichols *et al*. found unidentified fungi on 4-year-old plantation trees, causing red spots and yellowing of leaves. Care should be taken when pruning to avoid wet weather, so that fungal entry into stems is minimized.

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Annex 1
Pest species distribution in the selected countries, by region

AFRICA

Pest species	Order/phylum: family	Ghana	Kenya	Malawi	Mauritius	Morocco	South Africa	Sudan
Insects								
Amyna punctum	Lepidoptera: Noctuidae		D N C					
Anacridum melanorhodon	Orthoptera: Acrididae							D N B
Analeptes trifasciata	Coleoptera: Cerambycidae	D N B						
Anaphe panda	Lepidoptera: Thaumetopoeidae			D N B				
Anaphe venata	Lepidoptera: Notodontidae	D N B						
Ancistrotermes latinotus	Isoptera: Termitidae			D N B				
Apate indistincta	Coleoptera: Bostrichidae		D P B					
Apate monachus	Coleoptera: Bostrichidae	D P B	D P B					
Apate terebrans	Coleoptera: Bostrichidae	D P B						
Bruchidius uberatus	Coleoptera: Bruchidae							D P B
Buzura abruptaria	Lepidoptera: Geometridae			D N C				
Caryedon serratus	Coleoptera: Bruchidae							D P B
Chrysobothris dorsata	Coleoptera: Buprestidae							T P B
Cinara cronartii	Hemiptera: Aphididae						T P C	
Cinara cupressivora	Hemiptera: Aphididae		T P C	T P C	T P C			
Cinara pinivora	Hemiptera: Aphididae		T P C					
Cisseis rufobasalis	Coleoptera: Buprestidae				D N B			
Coryphodema tristis	Lepidoptera: Cossidae						D P B	

T= Introduced pest
D= Indigenous pest
P= Planted forest
N= Naturally regenerated forest
B= Broadleaf trees
C= Coniferous trees

Pest species	Order/phylum: family	Ghana	Kenya	Malawi	Mauritius	Morocco	South Africa	Sudan
Cubitermes spp.	Isoptera: Termitidae			D N B				
Diclidophlebia eastopi	Hemiptera: Psyllidae	D P B						
Distantiella theobroma	Hemiptera: Miridae	D P B						
Dysmicoccus brevipes	Hemiptera: Pseudococcidae		D P B					
Ellimenistes laesicollis	Coleoptera: Curculionidae						D P B	
Epicerura pulverulenta	Lepidoptera: Notodontidae	D P B						
Eulachnus rileyi	Hemiptera: Aphididae		T P C	T P C				
Euproctis terminalis	Lepidoptera: Lymantriidae						D P C	
Gonipterus scutellatus	Coleoptera: Curculionidae		T P B		T P B		T P B	
Gonometa podocarpi	Lepidoptera: Lasiocampidae		D N C					
Helopeltis lalandei	Hemiptera: Miridae	D P B						
Heteropsylla cubana	Hemiptera: Psyllidae		T P B	T P B	T P B			T P B
Hodotermes mossambicus	Isoptera: Hodotermitidae			D N B				
Hylastes angustatus	Coleoptera: Curculionidae						T P C	
Hylurgus ligniperda	Coleoptera: Scolytidae						T P C	
Hypsipyla grandella	Lepidoptera: Pyralidae				T P B			
Hypsipyla robusta	Lepidoptera: Pyralidae	T P B			T P B			
Imbrasia cytherea	Lepidoptera: Saturnidae						D P C	
Kotochalia junodi	Lepidoptera: Psychidae						D P B	
Lamprosema lateritialis	Lepidoptera: Pyralidae	D N B						
Leptocybe invasa	Hymenoptera: Eulophidae		T P B			T P B	T P B	
Lygidolon laevigatum	Hemiptera: Miridae						D P B	
Lymantria dispar	Lepidoptera: Lymantriidae					D N B		
Macrotermes falciger	Isoptera: Termitidae			D N B				
Mesoplatys cincta	Coleoptera: Chrysomelidae	D P B						

T= Introduced pest P= Planted forest B= Broadleaf trees
D= Indigenous pest N= Naturally regenerated forest C= Coniferous trees

Pest species	Order/phylum: family	Ghana	Kenya	Malawi	Mauritius	Morocco	South Africa	Sudan
Microtermes spp.	Isoptera: Termitidae			D N B				
Nezara robusta	Hemiptera: Pentatomidae			D N B				
Odontotermes spiniger	Isoptera: Termitidae			D N B				
Oemida gahani	Coleoptera: Cerambycidae		D N C					
Orthotomicus erosus	Coleoptera: Scolytidae					D P C		
Pachypasa capensis	Lepidoptera: Lasiocampidae						D P B/C	
Phoracantha recurva	Coleoptera: Cerambycidae			T P B		T P B	T P B	
Phoracantha semipunctata	Coleoptera: Cerambycidae			T P B		T P B	T P B	
Phytolyma fusca	Hemiptera: Psyllidae	D P B						
Phytolyma lata	Hemiptera: Psyllidae	D P B						
Pineus pini	Hemiptera: Adelgidae		T P C	T P C			T P C	
Pissodes nemorensis	Coleoptera: Curculionidae						T P C	
Plagotriptus pinivorus	Orthoptera: Eumasticidae			D N C				
Pseudocanthotermes militaris	Isoptera: Termitidae			D N B				
Sahlbergella singularis	Hemiptera: Miridae	D P B						
Salagena discata	Lepidoptera: Cossidae		D N B					
Scolytus kirschii	Coleoptera: Scolytidae						T P B	
Sirex noctilio	Hymenoptera: Siricidae						T P C	
Sphenoptera chalcichroa arenosa	Coleoptera: Buprestidae							D N/P B
Sphenoptera fulgens	Coleoptera: Buprestidae							D N/P B
Strepsicrates rhothia	Lepidoptera: Tortricidae	D P B						
Thaumastocoris peregrinus	Hemiptera: Thaumastocoridae						T P B	
Thaumetopoea bonjeani	Lepidoptera: Notodontidae					D N C		
Thaumetopoea libanotica	Lepidoptera: Thaumetopoeidae					D N C		
Thaumetopoea pityocampa	Lepidoptera: Notodontidae					D P C		

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Pest species	Order/phylum: family	Ghana	Kenya	Malawi	Mauritius	Morocco	South Africa	Sudan
Trachyostus ghanaensis	Coleoptera: Platypodidae	D N B						
Tridesmodes ramiculata	Lepidoptera: Thyrididae	D P B						
Xasinthisa tarsispina	Lepidoptera: Geometridae			D N C				
Zonocerus elegans	Orthoptera: Pyrgomorphidae			D N B/C				
Diseases								
Armillaria fuscipes	Basidiomycota: Marasmiaceae						D N/P B/C	
Armillaria heimii	Basidiomycota: Marasmiaceae		T P B/C					
Armillaria mellea	Basidiomycota: Marasmiaceae		T P B/C	T N B/C				T P B
Armillaria spp.	Basidiomycota: Marasmiaceae		D N B		D P C			
Botryosphaeria dothidea	Ascomycota: Botryosphaeriaceae						T P B	
Botryosphaeria eucalypticola	Ascomycota: Botryosphaeriaceae						T P B	
Botryosphaeria eucalyptorum	Ascomycota: Botryosphaeriaceae						T P B	
Botryosphaeria spp.	Ascomycota: Incertae sedis		T P B	T N B/C				
Botrytis cinerea	Ascomycota: Sclerotiniaceae			T N C				
Ceratocystis albofundus	Ascomycota: Ceratocystidaceae						T N/P B	
Ceratocystis spp.	Ascomycota: Ceratocystidaceae		T P B					
Chrysoporthe austroafricana	Ascomycota: Incertae sedis						D N/P B	
Fusarium spp.	Ascomycetes: Nectriaceae			T N B/C				
Gibberella circinata	Ascomycota: Nectriaceae						T P C	
Holocryphia eucalypti	Ascomycota: Valsaceae						T P B	
Lepteutypa cupressi	Ascomycota: Amphisphaeriaceae		D P C				D P C	
Mycosphaerella pini	Ascomycota: Mycosphaerellaceae		T P C				T P C	
Nattrassia mangiferae	Ascomycota: Incertae sedis							T P B
Nectria rigidiuscula	Ascomycota: Nectriaceae	T P B						
Phanerochaete salmonicolor	Basidiomycota: Phanerochaetaceae						T N/P B	

T= Introduced pest P= Planted forest B= Broadleaf trees
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Pest species	Order/phylum: family	Ghana	Kenya	Malawi	Mauritius	Morocco	South Africa	Sudan
Phytophthora cinnamomi	Oomycota: Pythiaceae						T N/P B	
Phytophthora nicotianae	Oomycota: Pythiaceae						T P B	
Rhizina undulata	Ascomycota: Rhizinaceae						T P C	
Sphaeropsis sapinea	Ascomycota: Incertae sedis		T P C				T P C	
Subramanianospora vesiculosa	Ascomycota: Incertae sedis				T P B			
Xanthomonas axonopodis p.v. *khayae*	Xanthomonadales: Xanthomonadaceae							D N B
Other pests								
Macaca sylvana	Primates: Cercopithecidae					D N/P C		

T= Introduced pest P= Planted forest B= Broadleaf trees
D= Indigenous pest N= Naturally regenerated forest C= Coniferous trees

ASIA AND THE PACIFIC

Pest species	Order/phylum: family	China	India	Indonesia	Mongolia	Thailand
Insects						
Acalolepta cervina	Coleoptera: Cerambycidae					D P B
Achaea janata	Lepidoptera: Noctuidae			D N B		
Achaea serva	Lepidoptera: Noctuidae			D N B		
Agrilus kalshoveni	Coleoptera: Buprestidae			D N B		
Alcidodes frenatus	Coleoptera: Curculionidae					D P B
Alcidodes ludificator	Coleoptera: Curculionidae					D P B
Anoplophora glabripennis	Coleoptera: Cerambycidae	D P B				
Apoderus notatus	Coleoptera: Curculionidae					D P B
Apriona cinerea	Coleoptera: Cerambycidae		D P B			
Archips micaceana	Lepidoptera: Tortricidae					D P B
Aristobia approximator	Coleoptera: Cerambycidae					D P B
Aristobia horridula	Coleoptera: Cerambycidae					D P B
Asphondylia tectonae	Diptera: Cecidomyiidae		D N B			
Aulacaspis marina	Hemiptera: Diaspidae			D P B		
Batocera rubus	Coleoptera: Cerambycidae					D P B
Brontispa longissima	Coleoptera: Chrysomelidae	T P B		D P B		T P B
Calliteara cerigoides	Lepidoptera: Lymantriidae			D P B		
Calopepla leayana	Coleoptera: Chrysomelidae		D P B			D P B
Catopsilia crocale crocale	Lepidoptera: Pieridae					D P B
Catopsilia pomona pomona	Lepidoptera: Pieridae					D P B
Catopsilia pyranthe pyranthe	Lepidoptera: Pieridae					D P B
Celosterna pollinosa sulphurea	Coleoptera: Cerambycidae					D P B
Chrysomela populi	Coleoptera: Chrysomelidae		D P B			

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Pest species	Order/phylum: family	China	India	Indonesia	Mongolia	Thailand
Clostera cupreata	Lepidoptera: Notodontidae		D P B			
Clostera fulgurita	Lepidoptera: Notodontidae		D P B			
Conogethes punctiferalis	Lepidoptera: Pyralidae	D P B				
Coptotermes curvignathus	Isoptera: Rhinotermitidae			D P B/C		D P B/C
Coptotermes gestroi	Isoptera: Rhinotermitidae					D P B
Craspedonta mouhoti	Coleoptera: Chrysomelidae					D P B
Cryptothelia cramerii	Lepidoptera: Psychidae		D N C			
Curculio davidi	Coleoptera: Curculionidae	D P B				
Cydia splendana	Lepidoptera: Tortricidae	D P B				
Cyrtotrachelus dichrous	Coleoptera: Curculionidae					D P B
Cyrtotrachelus longimanus	Coleoptera: Curculionidae					D P B
Dasychira mendosa	Lepidoptera: Lymantriidae					D P B
Dendroctonus valens	Coleoptera: Scolytidae	T P C				
Dendrolimus punctatus	Lepidoptera: Lasiocampidae	D P C				
Dendrolimus sibiricus	Lepidoptera: Lasiocampidae	D N C			D N/P C	
Dendrolimus tabulaeformis	Lepidoptera: Lasiocampidae	D N C				
Dichocrocis punctiferalis	Lepidoptera: Pyralidae					D P B
Dioryctria rubella	Lepidoptera: Pyralidae			D P C		
Ectropis deodarae	Lepidoptera: Geometridae		D N C			
Erannis jacobsoni	Lepidoptera: Geometridae				D N/P C	
Eucosma hypsidryas	Lepidoptera: Tortricidae		D N C			
Eumeta variegata	Lepidoptera: Psychidae			D N B/C		
Eurema blanda	Lepidoptera: Pieridae			D P B		
Eutectona machaeralis	Lepidoptera: Pyralidae		D N/P B			D N/P B
Euwallacea destruens	Coleoptera: Scolytidae			D P B		

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Pest species	Order/phylum: family	China	India	Indonesia	Mongolia	Thailand
Euwallacea fornicatus	Coleoptera: Scolytidae			D P B		
Glena indiana	Coleoptera: Cerambycidae					D P B
Helopeltis theivora	Hemiptera: Miridae			D P B		
Hemiberlesia pitysophila	Hemiptera: Diaspidae	T P C				
Heteropsylla cubana	Hemiptera: Psyllidae		T P B	T P B		T P B
Holotrichia sp. near *longicarinata*	Coleoptera: Scarabaeidae					D P B
Hoplocerambyx spinicornis	Coleoptera: Cerambycidae		D N B			
Hyblaea puera	Lepidoptera: Hyblaeidae		D P B	D P B		D N B
Hyphantria cunea	Lepidoptera: Arctiidae	T N B				
Hypomeces squamosus	Coleoptera: Curculionidae					D P B
Hypsipyla robusta	Lepidoptera: Pyralidae		D P B	D P B		D P B
Icerya purchasi	Hemiptera: Margarodidae		T P B			
Indarbela quadrinotata	Lepidoptera: Cossidae			D P B		
Indarbela spp.	Lepidoptera, Metarbelidae					D P B
Ips sexdentatus	Coleoptera: Scolytidae				D N/P C	D P C
Ips subelongatus	Coleoptera: Scolytidae				D N/P B/C	
Leptocentrus spp.	Hemiptera: Membracidae					D P B
Leptocybe invasa	Hymenoptera: Eulophidae		T P B			
Leucoma salicis	Lepidoptera: Lymantriidae				D N/P B	
Lymantria dispar	Lepidoptera: Lymantriidae	D N B/C			D N/P B/C	
Lymantria lepcha	Lepidoptera: Lymantriidae			D N B		
Lymantria mathura	Lepidoptera: Pyralidae		D P B			
Lymantria obfuscata	Lepidoptera: Lymantriidae		D P B			
Machaerota elegans	Hemiptera: Cercopidae					D P B
Melanophila cyanea	Coleoptera: Buprestidae				D N/P C	

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Pest species	Order/phylum: family	China	India	Indonesia	Mongolia	Thailand
Micropistus sp.	Coleoptera: Buprestidae					D P B
Milionia basalis	Lepidoptera: Geometridae			D N/P B/C		
Mylabris phalerata	Coleoptera: Meloidae					D P B
Neotermes tectonae	Isoptera: Kalotermitidae			D P B		
Niphades castanea	Coleoptera: Curculionidae	D P B				
Oracella acuta	Hemiptera: Pseudococcidae	T P C				
Orgyia antiqua	Lepidoptera: Lymantriidae				D N/P B/C	
Orthotomicus suturalis	Coleoptera: Scolytidae				D N/P C	
Pagyda salvalis	Lepidoptera: Pyralidae					D P B
Paliga damastesalis	Lepidoptera: Pyralidae					D P B
Phassus signifer	Lepidoptera: Hepialidae					D P B
Physomerus grossipes	Coleoptera: Coreidae					D P B
Pineus pini	Hemiptera: Adelgidae		T P C			
Pionea aureolalis	Lepidoptera: Pyralidae					D P B
Prioptera spp.	Lepidoptera: Pyralidae					D P B
Pseudoregma sp.	Hemiptera: Pemphigidae					D P B
Psilogramma menephron	Lepidoptera: Sphingidae					D P B
Pteroma plagiophleps	Lepidoptera: Psychidae			D P B		
Quadraspidiotus perniciosus	Hemiptera: Coccidae		T P B			
Sagra femorata	Coleoptera: Chrysomelidae					D P B
Scolytus morawitzi	Coleoptera: Scolytidae				D N/P C	
Sinoxylon anale	Coleoptera: Bostrychidae					D P B
Sternocera spp.	Coleoptera: Buprestidae					D P B
Tetropium gracilicorne	Coleoptera: Cerambycidae				D N/P C	
Tingis beesoni	Hemiptera: Tingidae					D P B

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Pest species	Order/phylum: family	China	India	Indonesia	Mongolia	Thailand
Tomicus minor	Coleoptera: Scolytidae				D N/P C	
Tomicus n.sp.	Coleoptera: Scolytidae	T P C				
Tomicus piniperda	Coleoptera: Scolytidae				D N/P C	
Valanga nigricornis	Orthoptera: Acrididae			D P B		
Voracia casuariniphaga	Lepidoptera: Lasiocampidae			D N B/C		
Xyleborus dispar	Coleoptera: Scolytidae				D N/P B	
Xyleutes ceramica	Lepidoptera: Cossidae			D P B		D N/P B
Xylosandrus compactus	Coleoptera: Scolytidae					D P B
Xylosandrus morigerus	Coleoptera: Scolytidae			D P B		
Xystrocera festiva	Coleoptera: Cerambycidae			D P B		
Zeuzera coffeae	Lepidoptera: Cossidae			D P B		D N/P B
Diseases						
Agrobacterium tumefaciens	Rhizobiales: Rhizobiaceae	D P B		D P B		
Balansia linearis	Ascomycota: Clavicipitaceae		D P B			
Botryosphaeria dothidea	Ascomycota: Botryosphaeriaceae					D P B
Chondroplea populea	Ascomycota: Valsaceae	D P B				
Chrysoporthe cubensis	Ascomycota: Valsaceae					T P B
Coniothyrium zuluense	Ascomycetes: Leptosphaeriaceae					T P B
Corticium salmonicolor	Basidiomycota: Corticiaceae			D P B		
Coryneum populinum	Ascomycota: Melanconidaceae	D P B				
Cryptosporiopsis eucalypti	Ascomycota: Dermateaceae					D P B
Cylindrocladium quinqueseptatum	Ascomycota: Nectriaceae					D P B
Dothiorella gregaria	Ascomycota: Botryosphaeriaceae	D P B				
Dothiorella gregaria	Ascomycota: Botryosphaeriaceae	D P C				
Drepanopeziza punctiformis	Ascomycota: Leotiales	D P B				

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Pest species	Order/phylum: family	China	India	Indonesia	Mongolia	Thailand
Endoraecium digitatum	Basidiomycota: Raveneliaceae			T P B		
Entoleuca mammata	Ascomycota: Xylariaceae			D P B		
Fusarium solani f. *dalbergiae*	Ascomycota: Nectriaceae		D P B			
Ganoderma philippii	Basidiomycota: Ganodermataceae			D P B		
Melampsora laricis-populina	Basidiomycota: Melampsoraceae	D P B				
Mycosphaerella populi	Ascomycota: Mycosphaerellaceae	D P B				
Nattrassia mangiferae	Ascomycota: Incertae sedis					D P B
Paulownia witches broom	Phytoplasma	D P B				
Phellinus noxius	Basidiomycota: Hymenochaetaceae			D P B		
Phytophthora palmivora	Oomycota: Pythiaceae			D P B		
Poria hypobrunnea	Basidiomycota: Polyporaceae			D P B		
Subramanianospora vesiculosa	Ascomycota: Incertae sedis		D P B			D P B
Tinctoporellus epimiltinus	Basidiomycota: Polyporaceae			D P B		
Valsa sordida	Ascomycota: Valsaceae	D P B				
Venturia populina	Ascomycota: Venturiaceae	D P B				
Other pests						
Apodemus spp.	Rodentia: Muridae	D P B/C				
Bursaphelenchus xylophilus	Tylenchida: Aphelenchoididae	T N/P C				

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EUROPE

Pest species	Order/phylum: family	Moldova	Romania	Russian Federation
Insects				
Apethymus filiformis	Hymenoptera: Tenthredinidae		D N B	
Archips crataegana	Lepidoptera: Tortricidae	D N B		
Archips xylosteana	Lepidoptera: Tortricidae	D N B		
Bupalus piniarius	Lepidoptera: Geometridae			D N/P C
Cameraria ohridella	Lepidoptera: Gracillariidae	T N B		
Choristoneura murinana	Lepidoptera: Tortricidae			D N/P B/C
Curculio spp.	Coleoptera: Curculionidae		D N B	
Cydia spp.	Lepidoptera: Tortricidae		D N B	
Dendrolimus sibiricus	Lepidoptera: Lasiocampidae			D N/P C
Diprion pini	Hymenoptera: Diprionidae		D P C	
Erannis defoliaria	Lepidoptera: Geometridae	D N B	D N B	
Euproctis chrysorrhoea	Lepidoptera: Lymantriidae		D N B	
Hylobius abietis	Coleoptera: Curculionidae		D N C	
Hyphantria cunea	Lepidoptera: Arctiidae	T N B	T N B	
Ips acuminatus	Coleoptera: Scolytidae		D N C	
Ips amitinus	Coleoptera: Scolytidae		D N C	
Ips cembrae	Coleoptera: Scolytidae		D N C	D N/P C
Ips sexdentatus	Coleoptera: Scolytidae		D N C	D N/P C
Ips typographus	Coleoptera: Scolytidae		D N C	D N/P C
Lymantria dispar	Lepidoptera: Lymantriidae	D N B/C	D N/P B/C	D N/P B/C
Lymantria monacha	Lepidoptera: Lymantriidae		D N B/C	D N/P B/C
Malacosoma neustria	Lepidoptera: Lasiocampidae		D N B	
Monochamus urussovi	Coleoptera: Cerambycidae			D N C

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Pest species	Order/phylum: family	Moldova	Romania	Russian Federation
Monochamus urussovi	Coleoptera: Cerambycidae			D P C
Neodiprion sertifier	Hymenoptera: Diprionidae		D P C	
Operophtera brumata	Lepidoptera: Geometridae	D N B	D N B	
Orthosia cruda	Lepidoptera: Noctuidae		D N B	
Pandemis cerasana	Lepidoptera: Tortricidae	D N B		
Pityogenes chalcographus	Coleoptera: Scolytidae		D N C	
Semasia rufimitrana	Lepidoptera: Tortricidae		D N C	
Stereonychus fraxini	Coleoptera: Curculionidae	D N B	D N B	
Tetropium castaneum	Coleoptera: Cerambycidae			D N/P C
Thaumetopoea processionea	Lepidoptera: Notodontidae		D N B	
Tomicus minor	Coleoptera: Scolytidae		D N C	
Tomicus piniperda	Coleoptera: Scolytidae		D N C	D N/P C
Tortrix viridana	Lepidoptera: Tortricidae	D N B	D N B	
Xylotrechus altaicus	Coleoptera: Cerambycidae			D N/P C
Yponomeuta rorellus	Lepidoptera: Yponomeutoidae		D N B	
Zeiraphera diniana	Lepidoptera: Tortricidae			D N/P C
Diseases				
Gremmeniella abietina	Ascomycota: Helotiaceae			D N/P C
Microsphaera abbreviata	Ascomycota: Erysiphaceae	D N B	D N/P B	
Nectria spp.	Ascomycota: Nectriaceae		D N B	
Other pests				
Cervus nippon	Artiodactyla: Cervidae	T N B		
Dama dama	Artiodactyla: Cervidae	T N B		
Nyctereutes procyonoides	Carnivora: Canidae	T N B		

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LATIN AMERICAN AND THE CARIBBEAN

Pest species	Order/phylum: family	Argentina	Belize	Brazil	Chile	Colombia	Honduras	Mexico	Uruguay
Insects									
Acrospila gastralis	Lepidoptera: Pyralidae					D P B			
Adelges cooleyi	Hemiptera: Adelgidae							T P C	
Amitermes foreli	Isoptera: Termitidae					D P B			
Amphicerus cornutus	Coleoptera: Bostrichidae					D P B			
Anomala pyropyga	Coleoptera: Scarabaeidae					D P B/C			
Anomis illita	Lepidoptera: Noctuidae					D P B			
Buprestis novemmaculata	Coleoptera: Buprestidae				T P C				
Cargolia arana	Lepidoptera: Geometridae					D P B/C			
Ceroys quadrispinosus	Orthoptera: Phasmidae					D P C			
Chilecomadia valdiviana	Lepidoptera: Cossidae				D N B				
Chionaspis pinifoliae	Hemiptera: Diaspidae							T P C	
Chrysobothris yucatanensis	Coleoptera: Buprestidae							D P B	
Cinara acutirostris	Hemiptera: Aphididae	T P C							
Cinara atlantica	Hemiptera: Aphididae			T P C					
Cinara cedri	Hemiptera: Aphididae	T P C							
Cinara costata	Hemiptera: Aphididae	T P C							
Cinara cupressi	Hemiptera: Aphididae				T N C				
Cinara cupressivora	Hemiptera: Aphididae				T N C	T P C			
Cinara fresai	Hemiptera: Aphididae	T P C		T P C	T N C				
Cinara juniperi	Hemiptera: Aphididae	T P C							
Cinara maghrebica	Hemiptera: Aphididae	T P C							
Cinara maritimae	Hemiptera: Aphididae	T P C		T P C	T P C				
Cinara piceae	Hemiptera: Aphididae	T P C							

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Pest species	Order/phylum: family	Argentina	Belize	Brazil	Chile	Colombia	Honduras	Mexico	Uruguay
Cinara pilicornis	Hemiptera: Aphididae	T P C							
Cinara piniformosana	Hemiptera: Aphididae			T P C					
Cinara pinivora	Hemiptera: Aphididae	T P C		T P C					
Cinara tujafilina	Hemiptera: Aphididae	T P C		T P C	T N C				
Coptotermes gestroi	Isoptera: Rhinotermitidae							T P B	
Ctenarytaina eucalypti	Hemiptera: Psyllidae				T P B				T P B
Ctenarytaina spatulata	Hemiptera: Psyllidae								T P B
Dendroctonus adjunctus	Coleoptera: Scolytidae							D N C	
Dendroctonus frontalis	Coleoptera: Scolytidae		D N C				D N C	D N C	
Dendroctonus mexicanus	Coleoptera: Scolytidae							D N C	
Dendroctonus pseudotsugae	Coleoptera: Scolytidae							D N C	
Dictyla monotropidia	Hemiptera: Tingidae					D P B			
Dirphia araucariae	Lepidoptera: Saturnidae			D N C					
Dynaspidiotus californicus	Hemiptera: Diaspidae							T P C	
Elatobium abietinum	Hemiptera: Aphididae	T P C							
Eulachnus rileyi	Hemiptera: Aphididae	T P C			T P C	T N/P C			
Eulachnus tauricus	Hemiptera: Aphididae	T P C							
Euryscopa cingulata	Coleoptera: Chrysomelidae					D P B			
Glena bisulca	Lepidoptera: Geometridae					D P B/C			
Glycaspis brimblecombei	Hemiptera: Psyllidae			T P B	T P B			T P B	
Gonipterus scutellatus	Coleoptera: Curculionidae				T P B				
Hedypathes betulinus	Coleoptera: Cerambycidae			D N B					
Heliothrips haemorrhoidalis	Thysanoptera: Thripidae					D P B			
Hemeroplanes parce	Lepidoptera: Sphingidae					D P B			
Holopterus chilensis	Coleoptera: Cerambycidae				D N B				

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Pest species	Order/phylum: family	Argentina	Belize	Brazil	Chile	Colombia	Honduras	Mexico	Uruguay
Hornius grandis	Coleoptera: Chrysomelidae				D N B				
Hylamorpha elegans	Coleoptera: Scarabaeidae				D N B				
Hylamorpha elegans	Coleoptera: Scarabaeidae				D N C				
Hylurgus ligniperda	Coleoptera: Scolytidae				D N C				
Hypsipyla grandella	Lepidoptera: Pyralidae	D P B	D P B	D P B		D P B		D P B	D P B
Ips calligraphus	Coleoptera: Scolytidae		D N C						
Ips confusus	Coleoptera: Scolytidae							D N C	
Ips grandicollis	Coleoptera: Scolytidae		D N C						
Ips pini	Coleoptera: Scolytidae							D N C	
Ips apache	Coleoptera: Scolytidae		D N C						
Lagynopteryx botulata	Lepidoptera: Geometridae				D N B				
Megalopyge orsilochus	Lepidoptera: Megalopygidae					D P B			
Megaplatypus mutatus	Coleoptera: Platypodidae	D P B		D P B					D N/P B
Melanolophia commotaria	Lepidoptera: Geometridae					D P C			
Minthea rugicollis	Coleoptera: Bostrichidae							T P B	
Nematus desantisi	Hymenoptera: Tenthredinidae	T P B			T P B				
Neuromelia albinearia	Lepidoptera: Geometridae					D P C			
Oncideres dejeani	Coleoptera: Cerambycidae			D N B					
Oncideres impluviata	Coleoptera: Cerambycidae			D N B					
Oncideres tessellata	Coleoptera: Cerambycidae					D P B			
Ormiscodes cinnamomea	Lepidoptera: Saturniidae				D P B/C				
Oxydia olivata	Lepidoptera: Geometridae					D P B			
Oxydia trychiata	Lepidoptera: Geometridae					D P C			
Paranthrene dollii	Lepidoptera: Sesiidae							T P B	
Phoracantha recurva	Coleoptera: Cerambycidae								T P B

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Pest species	Order/phylum: family	Argentina	Belize	Brazil	Chile	Colombia	Honduras	Mexico	Uruguay
Phoracantha semipunctata	Coleoptera: Cerambycidae				T P B				
Planudes cortex	Orthoptera: Phasmidae					D P C			
Pseudohylesinus variegatus	Coleoptera: Scolytidae							D N C	
Reticulitermes lucifugus	Isoptera: Rhinotermitidae								T N/P B/C
Rhyacionia buoliana	Lepidoptera: Tortricidae	T P C			T P C				
Rugitermes sp.	Isoptera: Kalotermitidae								T N/P B/C
Sarsina violascens	Lepidoptera: Lymantriidae	D P B		D P B				D P B	
Scolytus multistriatus	Coleoptera: Scolytidae							T P B	
Sirex noctilio	Hymenoptera: Siricidae	T P C		T P C	T P C				T P C
Steirastoma histrionicum	Coleoptera: Cerambycidae					D P B			
Thyrinteina arnobia	Lepidoptera: Geometridae			D P B					
Tremex fuscicornis	Hymenoptera: Siricidae				T P B				
Urocerus gigas	Hymenoptera: Siricidae	T P C			T P C				
Warrenaria sp.	Lepidoptera: Geometridae				D N B				
Xylosandrus morigerus	Coleoptera: Scolytidae							T P B	
Diseases									
Armillaria spp.	Basidiomycota: Marasmiaceae			D P C					
Botryosphaeria dothidea	Ascomycota: Botryosphaeriaceae								T P B
Botryosphaeria ribis	Ascomycota: Botryosphaeriaceae				T P B/C				
Ceratocystis fimbriata	Ascomycota: Ceratocystidaceae			T P B					T P B
Chrysoporthe cubensis	Ascomycota: Incertae sedis			T P B		T P B			
Coniothyrium zuluense	Ascomycota: Incertae sedis								T P B
Fusarium subglutinans f. sp. *pini*	Ascomycota: Nectriaceae							T P C	
Melampsora medusae	Basidiomycota: Melampsoraceae			T P B					
Mycosphaerella pini	Ascomycota: Mycosphaerellaceae				T P C				

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Pest species	Order/phylum: family	Argentina	Belize	Brazil	Chile	Colombia	Honduras	Mexico	Uruguay
Mycosphaerella sp.	Ascomycota: Mycosphaerellaceae								T P B
Phanerochaete salmonicolor	Basidiomycota: Phanerochaetaceae			T P B					
Puccinia psidii	Basidiomycota: Pucciniaceae			D P B					D P B
Sphaeropsis sapinea	Ascomycota: Incertae sedis				T P C				
Other pests									
Arceuthobium spp.	Santalales: Visaceae							D N C	
Capra hircus	Artiodactyla: Bovidae				T N B				
Castor canadensis	Rodentia: Castoridae	T N B			T N B				
Cebus paella	Primata: Cebidae			D P C					
Cervus elaphus	Artiodactyla: Cervidae				T N B/C				
Lama guanicoe	Artiodactyla: Camelidae				D N B				
Lepus capensis	Lagomorpha: Leporidae				T N B/C				
Misodendrum spp.	Santalales: Misodendraceae				D N B/C				
Oryctolagus cuniculus	Lagomorpha: Leporidae				T P B/C				
Phoradendron spp.	Santalales: Visaceae							D N B	
Psittacanthus spp.	Santalales: Loranthaceae						D N C	D N B/C	
Subanguina chilensis	Tylenchida: Tylenchidae				D N B				
Tetranychus desertorum	Acarina: Tetranychidae					D P B			

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NEAR EAST

Pest species	Order/phylum: family	Cyprus	Kyrgyzstan
Insects			
Adelges japonicus	Hemiptera: Adelgidae		D P C
Aeolesthes sarta	Coleoptera: Cerambycidae		T N/P B
Agonoscena viridis	Hemiptera: Aphalaridae		D P B
Anthaxia bicolor	Coleoptera: Buprestidae		D P C
Anthaxia conradti	Coleoptera: Buprestidae		D N C
Anthaxia turkestanica	Coleoptera: Buprestidae		D P C
Aonidia isfarensis	Hemiptera: Diaspididae		D N C
Argyrestia praecocella	Lepidoptera: Argyresthiidae		D N C
Caliroa cerasi	Hymenoptera: Tenthredinidae		D N/P B
Capnodis sexmaculata	Coleoptera: Buprestidae		D N B
Capnodis tenebricosa	Coleoptera: Buprestidae		D N B
Carphoborus persicus	Coleoptera: Scolytidae		D N B
Carpocapsa pomonella	Lepidoptera: Torticidae		D N B
Cinara grossa	Hemiptera: Lachnidae		D P C
Contarinia spp.	Diptera: Cecidomyiidae		D N C
Erannis defoliaria	Lepidoptera: Geometridae		D N B
Erschoviella musculana	Lepidoptera: Noctuidae		D N B
Eurytoma plotnikovi	Hymenoptera: Eurytomidae		D N B
Hylastes substriatus	Coleoptera: Curclionidae		D P C
Hylesinus prytenskyi	Coleoptera: Scolytidae		D N B
Hylesinus tupolevi	Coleoptera: Scolytidae		D N B
Hyphantria cunea	Lepidoptera: Arctiidae		T P B
Ips hauseri	Coleoptera: Scolytidae		D P C
Labidostomis stenostoma	Coleoptera: Chrysomelidae		D P B
Lymantria dispar	Lepidoptera: Lymantriidae	D N/P B	D N/P B
Malacosoma parallela	Lepidoptera: Lasiocampidae		D N/P B
Megastigmus certus	Hymenoptera: Torymidae		D N C
Megastigmus juniperi	Hymenoptera: Torymidae		D N C
Megastigmus validus	Hymenoptera: Torymidae		D N C
Melanophila cuspidata	Coleoptera: Buprestidae		D N B

T= Introduced pest
D= Indigenous pest
P= Planted forest
N= Naturally regenerated forest
B= Broadleaf trees
C= Coniferous trees

Pest species	Order/phylum: family	Cyprus	Kyrgyzstan
Melasoma populi	Coleoptera: Chrysomelidae		D P B
Molorchus kiesenwetteri	Coleoptera: Cerambycidae		D P C
Molorchus pallidipennis	Coleoptera: Cerambycidae		D P B/C
Tomicus destruens	Coleoptera: Scolytidae	D N/P C	
Orthotomicus erosus	Coleoptera: Scolytidae	D N/P C	
Panaphis juglandis	Hemiptera: Drepanosiphidae		D N B
Phloeosinus armatus	Coleoptera: Scolytidae	D N/P C	
Phloeosinus turkestanicus	Coleoptera: Scolytidae		D N/P C
Pineus pini	Hemiptera: Adelgidae		D P C
Pityogenes spessivtsevi	Coleoptera: Scolytidae		D P C
Pityophthorus parfentjevi	Coleoptera: Scolytidae		D P C
Pityophthorus schrenkianus	Coleoptera: Scolytidae		D P C
Prionus turkestanicus	Coleoptera: Cerambycidae		D N B
Pseudococcus comstocki	Hemiptera: Pseudococcidae		T N B
Quadraspidiotus perniciosus	Hemiptera: Diaspididae		T N B
Recurvaria pistaciicola	Lepidoptera: Gelechiidae		D N B
Rhopalopus nadari	Coleoptera: Buprestidae		D N B
Scolytus mali	Coleoptera: Scolytidae		D N B
Sphaerolecanium prunastri	Hemiptera: Coccidae		T N/P B
Tetropium staudingeri	Coleoptera: Cerambycidae		D P B/C
Thaumetopoea wilkinsoni	Lepidoptera: Thaumetopoeidae	D N/P C	
Tomicus minor	Coleoptera: Scolytidae	D N/P C	
Xyleborus saxeni	Coleoptera: Scolytidae		D N B
Xylotrechus namanganensis	Coleoptera: Cerambycidae		D N B
Yponomeuta malinellus	Lepidoptera: Yponomeutoidae		D N B
Yponomeuta padellus	Lepidoptera: Yponomeutoidae		D N B
Tomicus piniperda	Coleoptera: Scolytidae	D N/P C	
Diseases			
Armillaria mellea	Basidiomycota: Marasmiaceae		D P C
Biscogniauxia mediterranea var. *mediterranea*	Ascomycota: Xylariaceae		D N B
Cenangium ferruginosum	Ascomycota: Helotiaceae		D P C
Fomes fomentarius	Basidiomycota: Polyporaceae		D N B

T= Introduced pest P= Planted forest B= Broadleaf trees
D= Indigenous pest N= Naturally regenerated forest C= Coniferous trees

Pest species	Order/phylum: family	Cyprus	Kyrgyzstan
Fomitopsis pinicola	Basidiomycota: Fomitopsidaceae		D P C
Ganoderma applanatum	Basidiomycota: Ganodermataceae		D N B
Gymnosporangium spp.	Basidiomycota: Pucciniaceae		D N C
Heterobasidion annosum	Basidiomycota: Bondarzewiaceae		D P C
Inonotus hispidus	Basidiomycota: Hymenochaetaceae		D N/P B
Laetiporus sulphureus	Basidiomycota: Polyporaceae		D N/P B
Phellinus chrysoloma	Basidiomycota: Hymenochaetaceae		D P C
Pyrofomes demidoffii	Basidiomycota: Polyporaceae		D N C
Other pests			
Aceria erinoea	Acarina: Eriophyoidae		D N B
Aceria sp.	Acarina: Eriophyidae		D P B
Aceria tristriatus	Acarina: Eriophyoidae		D N B
Arceuthobium oxycedri	Santalales: Viscaceae		D N C
Eriophyes dispar	Acarina: Eriophyidae		D P B
Eriophyes mali	Acarina: Eriophyoidae		D N B
Eriophyes parapopuli	Acarina: Eriophyidae		D P B
Eriophyes phloeocoptes	Acarina: Eriophyoidae		D N B
Eriophyes pyri	Acarina: Eriophyoidae		D N B
Eriophyes tarbinskii	Acarina: Eriophyoidae		D N B
Phyllocoptes aegerenus	Acarina: Eriophyidae		D P B
Trisetacus kirghisorum	Acarina: Eriophyoidae		D N C

T= Introduced pest D= Indigenous pest P= Planted forest N= Naturally regenerated forest B= Broadleaf trees C= Coniferous trees

Annex 2
Pest species mentioned in Part III

Pest species	Order/phylum: family
Insects	
Acanthococcus danzigae Miller & Gimpel	Hemiptera: Eriococcidae
Achaea lienardi Boisduval	Lepidoptera: Noctuidae
Acherontia lachesis (Fabricius)	Lepidoptera: Sphingidae
Acrobasis demotella Grote	Lepidoptera: Pyralidae
Acromyrmex spp.	Hymenoptera: Formicidae
Adelges piceae (Ratzeberg)	Hemiptera: Adelgidae
Agriolima agrestis	Coleoptera: Elateridae
Agrotis segetum Denis & Schiffermuller	Lepidoptera: Noctuidae
Alcidodes ludificator (=gmelinae)	Coleoptera: Curculionidae
Anoplognathus sp.	Coleoptera: Scarabaeidae
Apate monachus Fabricius	Coleoptera: Bostrichidae
Apophylia nigricollis	Coleoptera: Chrysomelidae
Arion spp.	Coleoptera: Elateridae
Artipus floridanus Horn	Coleoptera: Curculionidae
Atta insularis Guérin-Méréville	Hymenoptera: Formicidae
Atta spp.	Hymenoptera: Formicidae
Attacus spp.	Lepidoptera: Saturniidae
Calopepla leayana (Latreille)	Coleoptera: Chrysomelidae
Camporatus sp.	Hymenoptera: Formicidae
Cardiaspina sp.	Hemiptera: Psyllidae
Catopyla dysorphnaea Bradly	Lepidoptera: Pyralidae
Choristoneura fumiferana (Clemens)	Lepidoptera: Tortricidae
Choristoneura occidentalis Freeman	Lepidoptera: Tortricidae
Chrysodeixis chalcites (Esper)	Lepidoptera: Noctuidae
Chrysomela populi Linnaeus	Coleoptera: Chrysomelidae
Chrysophtharta spp.	Coleoptera: Chrysomelidae
Chrysoteuchia topiaria (Zeller)	Lepidoptera: Pyralidae
Clastoptera undulata (Uhl.)	Hemiptera: Cercopidae
Cledus obesus Hustache	Coleoptera: Curculionidae
Clostera spp.	Lepidoptera: Notodontidae
Colaspis favosa Say	Coleoptera: Chrysomelidae
Conotrachelus retentus (Say)	Coleoptera: Curculionidae

Pest species	Order/phylum: family
Contarinia fagi (Hartig)	Diptera: Cecidomyiidae
Contarinia oregonensis Foote	Diptera: Cecidomyiidae
Contarinia washingtonensis Johnson	Diptera: Cecidomyiidae
Coptotermes curvignathus Holmgren	Isoptera: Rhinotermitidae
Coptotermes formosanus (Shiraki)	Isoptera: Rhinotermitidae
Coptotermes sp.	Isoptera: Rhinotermitidae
Cossula spp.	Lepidoptera: Cossidae
Cossus cadambae Moore	Lepidoptera: Cossidae
Cossus cossus Linnaeus	Lepidoptera: Cossidae
Crossotarsus externedentatus Fairmaire	Coleoptera: Platypodidae
Cryptococcus fagisuga Lindinger	Hemiptera: Eriococcidae
Cryptorhynchus lapathi Linnaeus	Coleoptera: Curculionidae
Cydia fagiglandana (Zeller)	Lepidoptera: Tortricidae
Dasychira pudibunda (Linnaeus)	Lepidoptera: Lymantriidae
Dasyneura fagicola Barnes	Diptera: Cecidomyiidae
Datana integerrima Grote & Robinson	Lepidoptera: Notodontidae
Dendroctonus frontalis Zimmermann	Coleoptera: Scolytidae
Dendroctonus mexicanus Hopkins	Coleoptera: Scolytidae
Dendroctonus pseudotsugae Hopkins	Coleoptera: Scolytidae
Dihammus cervinus (Hope)	Coleoptera: Cerambycidae
Dioryctria abietivorella Grote	Lepidoptera: Pyralidae
Dryocoetes confuses Swaine	Coleoptera: Scolytidae
Duomitus ceramicus Walker	Lepidoptera: Cossidae
Earomyia spp.	Diptera: Lonchaeidae
Elatobium abietinum (Walker)	Hemiptera: Aphididae
Endoxyla spp.	Lepidoptera: Cossidae
Ennomos quercinaria (Hufnagel)	Lepidoptera: Geometridae
Epithora dorsalis McL.	Coleoptera: Cerambycidae
Eriococcus coriaceus Maskell	Hemiptera: Eriococcidae
Eumeta variegata (Snellen)	Lepidoptera: Psychidae
Eurymela sp.	Hemiptera: Eurymelinae
Eurymeloides sp.	Hemiptera: Eurymelinae
Exophthalmus spp.	Coleoptera: Curculionidae
Gilletteella cooleyi Gillette	Hemiptera: Adelgidae
Gonipterus gibberus Boisduval	Coleoptera: Curculionidae
Gonipterus scutellatus Gyllenhal, 1833	Coleoptera: Curculionidae
Gonipterus spp.	Coleoptera: Curculionidae
Gypsonoma aceriana Duponchel	Lepidoptera: Tortricidae
Gyroptera robertsi Bradley	Lepidoptera: Pyralidae

Pest species	**Order/phylum: family**
Halymorpha picus (Fabricius)	Hemiptera: Pentatomidae
Holotrichia spp.	Coleoptera: Scarabaeidae
Hyblaea puera (Cramer)	Lepidoptera: Hyblaeidae
Hylecoetus dermestoides Linnaues	Coleoptera: Lymexylidae
Hyphantria cunea Drury	Lepidoptera: Arctiidae
Hypsipyla grandella (Zeller)	Lepidoptera: Pyralidae
Hypsipyla robusta (Moore)	Lepidoptera: Pyralidae
Icerya purchasi Maskell	Hemiptera: Margarodidae
Imbrasia cytherea Fabricius	Lepidoptera: Saturniidae
Ips grandicollis Eichhoff	Coleoptera: Scolytidae
Leucoma salicis Linnaeus	Lepidoptera: Lymantriidae
Leucoptera sinuella (Ruetti)	Lepidoptera: Lyonetiidae
Lyctus spp.	Coleoptera: Lyctidae
Lymantria dispar Linnaeus	Lepidoptera: Lymantriidae
Megastigmus spermotrophus Wachtl	Hymenoptera: Torymidae
Mnesampela privata (Guenée)	Lepidoptera: Geometridae
Oncideres cingulata (Say)	Coleoptera: Cerambycidae
Operophtera brumata Linnaeus	Lepidoptera: Geometridae
Operophtera fagata (Scharfenberg)	Lepidoptera: Geometridae
Orgyia pseudotsugata McDunnough	Lepidoptera: Lymantriidae
Otiorhynchus ovatus (Linnaeus)	Coleoptera: Curculionidae
Oxyops spp.	Coleoptera: Curculionidae
Ozola minor (Moore)	Lepidoptera: Geometridae
Paliga damastesalis Walker	Lepidoptera: Pyralidae
Paliga machoeralis (Walker)	Lepidoptera: Pyralidae
Paranthrene dollii (Neumogen)	Lepidoptera: Sesiidae
Paranthrene tabaniformis Rottemburg	Lepidoptera: Sesiidae
Paropsis spp.	Coleoptera: Chrysomelidae
Phassus excrescens (Butler)	Lepidoptera: Hepialidae
Phloeomyzus passerinii (Signoret)	Hemiptera: Aphididae
Phoracantha acanthocera (Macleay)	Coleoptera: Cerambycidae
Phoracantha semipunctata (Fabricius)	Coleoptera: Cerambycidae
Phoracantha spp.	Coleoptera: Cerambycidae
Phylacteophaga froggatti Riek	Hymenoptera: Pergidae
Pineus pini Gmelin	Hemiptera: Adelgidae
Pissodes spp.	Coleoptera: Curculionidae
Pissodes strobi (Peck)	Coleoptera: Curculionidae
Platypus gerstaeckeri Chapuis	Coleoptera: Platypodidae
Platypus spp.	Coleoptera: Platypodidae

Pest species	Order/phylum: family
Pseudophacopteron zimmerani	Hemiptera: Psyllidae
Rhyacionia buoliana Denis & Schiffermüller	Lepidoptera: Tortricidae
Rhyacionia spp.	Lepidoptera: Tortricidae
Rhynchaenus fagi (Linnaeus)	Coleoptera: Curculionidae
Sahyadrassus malabaricus (Moore)	Lepidoptera: Hepialidae
Saperda carcharias Linnaeus	Coleoptera: Cerambycidae
Scolytus spp.	Coleoptera: Scolytidae
Scolytus ventralis Leconte	Coleoptera: Scolytidae
Sinoxylon anale Lesne	Coleoptera: Bostrichidae
Sinoxylon sp.	Coleoptera: Bostrichidae
Sirex noctilio Fabricius	Hymenoptera: Siricidae
Thaumetopoea pityocampa Denis & Schiffermüller	Lepidoptera: Thaumetopoeidae
Tingis beesoni (Drake)	Hemiptera: Tingidae
Udinia faraquarsoni (Newest)	Hemiptera: Diaspididae
Umbonia crassicornis (Amyot & Serville)	Hemiptera: Membracidae
Xyleborus crassiusculus (Motschulsky)	Coleoptera: Scolytidae
Xyleborus perforans (Wollatson)	Coleoptera: Scolytidae
Xyleborus semiopacus (Motschulsky)	Coleoptera: Scolytidae
Xyleborus sharpi Blandford	Coleoptera: Scolytidae
Xyleborus sp.	Coleoptera: Scolytidae
Xyleutes ceramicus Walker	Lepidoptera: Cossidae
Xylosandrus compactus (Eichhoff)	Coleoptera: Scolytidae
Xylosandrus germanus (Blandford)	Coleoptera: Scolytidae
Xyloterus domesticus (Linnaeus)	Coleoptera: Scolytidae
Xystocera sp.	Coleoptera: Cerambycidae
Zeuzera coffeae Nietner	Lepidoptera: Cossidae
Zonocerus variegatus (Linnaeus)	Orthoptera: Pyrgomorphidae
Diseases	
Agrobacterium tumefaciens Smith & Townsend	Rhizobiales: Rhizobiaceae
Armillaria mellea (Vahl) P. Kumm	Basidiomycota: Marasmiaceae
Armillaria spp.	Basidiomycota: Marasmiaceae
Endoraecium digitatum (G. Winter) M. Scholler & Aime	Basidiomycota: Pileolariaceae
Botryosphaeria ribis Grossenb. & Duggar	Ascomycota: Botryosphaeriaceae
Ceratocystis fimbriata Ellis & Halsted	Ascomycota: Ceratocystidaceae
Chaetophoma sp.	Ascomycota: Incertae sedis
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc.	Ascomycota: Glomerellaceae
Coriolopsis sanguinaria (Klotzsch) Teng	Basidiomycota: Polyporaceae
Corticium rolfsii Curzi	Basidiomycota: Corticiaceae
Corticium salmonicolor Berk. & Broome	Basidiomycota: Corticiaceae

Pest species	Order/phylum: family
Cryptodiaporthe populea (Sacc.) Butin ex Butin 1958	Ascomycota: Valsaceae
Cylindrocladium ovatum sp. *novus*	Ascomycota: Nectriaceae
Cylindrocladium quinqueseptatum Figueiredo & Namekata	Ascomycota: Nectriaceae
Cylindrocladium scoparium Morgan	Ascomycota: Nectriaceae
Cylindrocladium spp.	Ascomycota: Nectriaceae
Echinodontium tinctorium Ellis & Everh.	Basidiomycota: Echinodontiaceae
Endocronartium harknessii Moore	Basidiomycota: Cronartiaceae
Fomes fomentarius (L.) Kickx	Basidiomycota: Polyporaceae
Fomes sp.	Basidiomycota: Polyporaceae
Fomitopsis cajanderi (P. Karst.) Kotl. & Pouzar	Basidiomycota: Fomitopsidaceae
Fomitopsis officinalis (Vill.) Bondartsev & Singer	Basidiomycota: Fomitopsidaceae
Fomitopsis pinicola (Sw.) P. Karst.	Basidiomycota: Fomitopsidaceae
Fusarium solani (Mart.) Sacc.	Ascomycota: Nectriaceae
Fusarium spp.	Ascomycota: Nectriaceae
Ganoderma sp.	Basidiomycota: Ganodermataceae
Gibberella circinata Nirenberg & O'Donnell	Ascomycota: Nectriaceae
Gibberella fujikuroi (Sawada) Wollenw.	Ascomycota: Nectriaceae
Gnomonia leptostyla (Fr.) Ces. & de Not.	Ascomycota: Valsaceae
Gnomonia sp.	Ascomycota: Valsaceae
Harknessia hawaiiensis F. Stevens & E. Young	Ascomycota: Incertae sedis
Apoharknessia insueta (B. Sutton) Crous & S.J. Lee	Ascomycota: Incertae sedis
Heterobasidion annosum (Fr.) Bref.	Basidiomycota: Bondarzewiaceae
Phellinus weirii (Murrill) Gilb.	Basidiomycota: Hymenochaetaceae
Maravalia achroa (Syd.) Arthur & Cummins	Basidiomycota: Chaconiaceae
Maravalia pterocarpi (Thirum.) Thirum.	Basidiomycota: Chaconiaceae
Drepanopeziza populorum (Desm.) Höhn.	Ascomycota: Dermateaceae
Melampsora laricis-populina Kleb.	Basidiomycota: Melampsoraceae
Meliola sp.	Ascomycota: Meliolaceae
Mycosphaerella pini Rostrup	Ascomycota: Mycosphaerellaceae
Davidiella populorum (G.E. Thomps.) Aptroot	Ascomycota: Mycosphaerellaceae
Mycosphaerella sp.	Ascomycota: Mycosphaerellaceae
Naemacyclus minor Butin	Ascomycota: Incertae sedis
Nectria coccinea (Pers.) Fr.	Ascomycota: Nectriaceae
Neonectria galligena (Bres.) Rossman & Samuels	Ascomycota: Nectriaceae
Olivea spp.	Basidiomycota: Chaconiaceae
Olivea tectonae (T.S. Ramakr. & K. Ramakr.) Thirum.	Basidiomycota: Chaconiaceae
Phaeocryptopus gaeumannii (T. Rohde) Petr.	Ascomycota: Incertae sedis
Phaeolus schweinitzii (Fr.) Pat.	Basidiomycota: Fomitopsidaceae
Phellinus gilvus (Schwein.) Pat.	Basidiomycota: Hymenochaetaceae

Pest species	Order/phylum: family
Phellinus noxius (Corner) G. Cunn	Basidiomycota: Hymenochaetaceae
Porodaedalea pini (Brot.) Murrill	Basidiomycota: Hymenochaetaceae
Phellinus spp.	Basidiomycota: Hymenochaetaceae
Pleurostomophora richardsiae (Nannf.) L. Mostert, W. Gams & Crous	Ascomycota: Pleurostomataceae
Phomopsis casuarinae (Tassi) Died.	Ascomycota: Diaporthaceae
Phomopsis spp.	Ascomycota: Diaporthaceae
Phomopsis tectonae D.P. Tiwari, R.C. Rajak & Nikhra	Ascomycota: Diaporthaceae
Phyllactinia guttata (Wallr.) Lév.	Ascomycota: Erysiphaceae
Pythium debaryanum R. Hesse	Oomycota: Pythiaceae
Pythium ultimum Trow	Oomycota: Pythiaceae
Phytophthora cactorum (Lebert & Cohn) J. Schröt.	Oomycota: Pythiaceae
Phytophthora cinnamomi Rands	Oomycota: Pythiaceae
Phytophthora spp.	Oomycota: Pythiaceae
Polyporus spp.	Basidiomycota: Polyporaceae
Poria sp.	Basidiomycota: Polyporaceae
Ralstonia solanacearum (Smith 1896) Yabuuchi *et al*.	Burkholderiales: Ralstoniaceae
Pseudomonas spp.	Pseudomonadales: Pseudomonadaceae
Pseudomonas tectonae Roldan & Andres	Pseudomonadales: Pseudomonadaceae
Pythium spp.	Oomycota: Pythiaceae
Readeriella mirabilis Syd. & P. Syd.	Ascomycota: Teratosphaeriaceae
Rhabdocline pseudotsugae Sydow	Ascomycota: Hemiphacidiaceae
Rhizina undulata Fr.	Ascomycota: Rhizinaceae
Thanatephorus cucumeris (A.B. Frank) Donk	Basidiomycota: Ceratobasidiaceae
Rhizoctonia spp.	Basidiomycota: Ceratobasidiaceae
Athelia rolfsii (Curzi) C.C. Tu & Kimbr.	Basidiomycota: Typhulaceae
Sphaceloma tsugii Hara	Ascomycota: Elsinoaceae
Sphaeropsis camarosporium	Ascomycota: Incertae sedis
Sphaeropsis sapinea (Fr.) Dyko & B.Sutton	Ascomycota: Incertae sedis
Subramanianospora vesiculosa (Butler) Narayanan, Sharma & Minter	Ascomycota: Incertae sedis
Thanatephorus cucumeris (Frank) Donk	Basidiomycota: Ceratobasidiaceae
Uredo sissoo Syd., Syd. & Butler	Basidiomycota: Incertae sedis
Uredo tesoensis Wakef.	Basidiomycota: Incertae sedis
Venturia populina (Vuill.) Fabricius	Ascomycota: Venturiaceae
Xanthomonas arboricola pv. *juglandis* (Pierce) Vauterin, Hoste, Kersters & Swings	Xanthomonadales: Xanthomonadaceae
Other pests	
Arceuthobium douglasii Engelmann	Santalales: Viscaceae
Dendrophthoe falcata (Lf) Ettingsh.	Santalales: Loranthaceae
Meloidogyne marioni (Cornu)	Tylenchida: Meloidogynidae

Annex 3
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FAO FORESTRY PAPER

Global review of forest pests and diseases

Forests are complex ecosystems that provide valuable products and services, have important aesthetic, social and cultural value and contribute to the livelihoods of rural communities. It is therefore critical to protect these resources from disturbances by insects and other pests and diseases. Pests and diseases can adversely affect tree growth, vigour and survival, the yield and quality of wood and non-wood products, wildlife habitat, recreation and the aesthetic appeal and cultural value of forests. They may also impede forest plantation programmes and make it necessary to abandon certain tree species or to clear cut large areas dominated by infested trees. Effective pest management requires reliable information about the biology, ecology and distribution of the pests, their impacts on forest ecosystems and possible methods of control; it also often requires international cooperation. This publication represents a rare effort to address forest pests and diseases comprehensively at the global level. Part I summarizes the results of a thematic study reviewing forest pests in 25 countries. Part II presents profiles of some globally important forest pest species, and Part III discusses select forest trees species and their associated pests. The information provided in this publication will assist forest health specialists, forest managers and policy-makers worldwide to make informed decisions.

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