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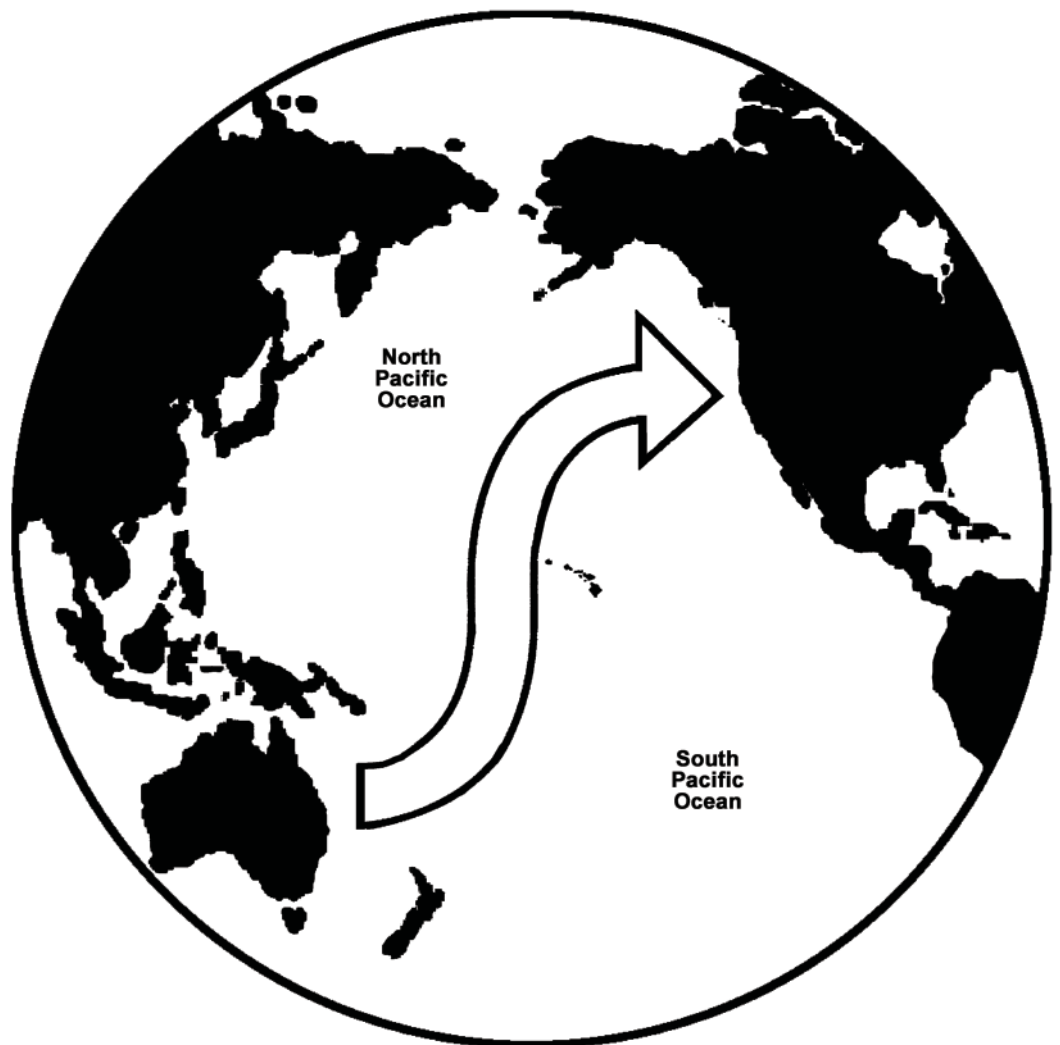Agriculture

Forest Service

Forest Health Protection

Forest Health Technology
Enterprise Team

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Pest Risk Assessment of the Importation into the United States of Unprocessed *Pinus* Logs and Chips from Australia

Abstract

The unmitigated pest risk potential for the importation of unprocessed logs and chips of species of *Pinus* (*Pinus radiata, P. elliottii* Engelm. var. *elliottii, P. taeda* L., and *P. caribaea* var. *hondurensis,* principally) from Australia into the United States was assessed by estimating the likelihood and consequences of introduction of representative insects and pathogens of concern. Eleven individual pest risk assessments were prepared, nine dealing with insects and two with pathogens. The selected organisms were representative examples of insects and pathogens found on foliage, on the bark, in the bark, and in the wood of *Pinus*.

Among the insects and pathogens assessed for logs as the commodity, high risk potentials were assigned to two introduced European bark beetles (*Hylurgus ligniperda* and *Hylastes ater*), the exotic bark anobiid (*Ernobius mollis*), ambrosia beetles (*Platypus subgranosus, Amasa truncatus*; *Xyleborus perforans*), an introduced wood wasp (*Sirex noctilio*), dampwood termite (*Porotermes adamsoni*), giant termite (*Mastotermes darwiniensis*), drywood termites (*Neotermes insularis*; *Kalotermes rufi notum, K. banksiae*; *Ceratokalotermes spoliator*; *Glyptotermes tuberculatus*; *Bifiditermes condonensis*; *Cryptotermes primus, C. brevis, C. domesticus, C. dudleyi, C. cynocephalus*), and subterranean termites (*Schedorhinotermes intermedius intermedius, S. i. actuosus, S. i. breinli, S. i. seclusus, S. reticulatus; Heterotermes ferox, H. paradoxus*; *Coptotermes acinaciformis, C. frenchi, C. lacteus, C. raffrayi*; *Microcerotermes boreus, M. distinctus, M. implicadus, M. nervosus, M. turneri*; *Nasutitermes exitiosis*). A moderate pest risk potential was assigned to pine loopers (*Chlenias* spp.), endemic weevils (*Aesiotes* spp.), *Sphaeropsis sapinea*, and the Armillaria root rot fungi (*Armillaria hinnulea, A. luteobubalina, A. novae-zealandiae,* and *A. pallidula*). When chips were considered as the commodity, the risk potentials dropped from high to moderate for the two bark beetles and the ambrosia beetles and dropped from high to low for the Sirex woodwasp and the dampwood, giant, drywood, and subterranean termites. The risk potentials for the Diplodia shoot blight pathogen and the Armillaria root rot fungi dropped from moderate to low for the chip commodity. For those organisms of concern that are associated with logs and chips of Australian *Pinus*, specific phytosanitary measures may be required to ensure the quarantine safety of proposed importations.

Keywords: pest risk assessment, *Pinus*, pine, Australia, log importation, chip importation

PEST RISK ASSESSMENT OF THE IMPORTATION INTO THE UNITED STATES OF UNPROCESSED *PINUS* LOGS AND CHIPS FROM AUSTRALIA

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EXECUTIVE SUMMARY

BACKGROUND AND OBJECTIVES

The objectives of this risk assessment were to identify the exotic pest organisms (insects and pathogens) that may be introduced with imported unprocessed *Pinus* logs and chips from Australia, assess the likelihood of the introduction and establishment in the United States of selected representative pests of *Pinus*, and assess the potential economic and environmental impacts that these pests may have on forest resources if established in the United States.

Current regulations require that unprocessed logs from temperate areas of Australia must be fumigated with methyl bromide or heat-treated to eliminate pests. Logs must be stored and handled to exclude access by pests after treatment (Title 7, CFR part 319.40-5(d), 319.40-6 (a)). The Animal and Plant Health Inspection Service (APHIS) requested that the Forest Service prepare a pest risk assessment that identifies the potential insects and pathogens of several species of *Pinus* (*P. radiata, P. elliottii* var. *elliottii, P. taeda, P. pinaster,* and *P. caribaea* var. *hondurensis*) throughout Australia, estimates the likelihood of their entry on Australian logs and chips into the United States, and evaluates the economic, environmental, and social consequences of such an introduction.

THE RISK ASSESSMENT TEAM

A USDA Forest Service Wood Import Pest Risk Assessment and Mitigation Evaluation Team (WIPRAMET) conducted the assessment. The team was chartered by the Chief of the Forest Service to provide a permanent source of technical assistance to APHIS in conducting pest risk assessments. WIPRAMET members and APHIS representatives traveled to Australia in September 2001. The team met with local agricultural, quarantine, and forestry officials, and with entomologists, pathologists, and forest industry representatives to gather information. Sub-teams toured harvest areas, inspected processing plants and ports, and viewed pest problems in eucalypt and pine plantations and forests in six states. The pest risk assessment document prepared by the team also takes into consideration comments by individuals who provided critical reviews of an earlier draft.

PEST RISK ASSESSMENT

The team compiled lists of insects and microorganisms known to be associated with *Pinus* species throughout Australia. From these lists, insects and pathogens that have the greatest risk potential as pests on imported logs or chips were identified. Eleven Individual Pest Risk Assessments (IPRAs) were prepared, nine dealing with insects and two dealing with pathogens. The objective was to include in the IPRAs representative examples of insects and pathogens found on foliage, on the bark, in the bark, and in the wood. By necessity, this pest risk assessment focuses on those insects and pathogens for which biological information is available.

However, by developing IPRAs for known organisms that inhabit a variety of different niches on logs, effective mitigation measures can subsequently be identified by APHIS to eliminate the recognized pests. It is assumed that any similar unknown organisms that inhabit the same niches would also be eliminated.

CONCLUSIONS

There are potential pest organisms found on *Pinus* spp. in Australia that have a high probability of being inadvertently introduced into the United States on unprocessed logs and chips. The potential mechanisms of log or chip infestation by pests are complex. Differences in harvesting practices, such as debarking, can influence the risk potential for pests that are hitchhikers or pests that invade the inner bark. Reducing debarked logs to chips will impact the survival and subsequent risk of importation of certain pests. Most insects would be adversely impacted by chipping, and of those for which IPRAs were done, many would be rated at moderate or low risk of surviving chipping and subsequent transport. Other organisms may not be affected by chipping (Armillaria root rot fungi for example). Differences between Australian states in the occurrence and extent of certain pest organisms are noted in the individual pest risk assessments. These differences may influence the risk potential for certain organisms from specific states.

Among the insects and pathogens assessed for logs as the commodity, high risk potentials were assigned to two introduced European bark beetles (*Hylurgus ligniperda* and *Hylastes ater*); the exotic bark anobiid (*Ernobius mollis*), ambrosia beetles (*Platypus subgranosus*, *Amasa truncatus*; *Xyleborus perforans*), an introduced wood wasp (*Sirex noctilio*), dampwood termite (*Porotermes adamsoni*), giant termite (*Mastotermes darwiniensis*), drywood termites (*Neotermes insularis*; *Kalotermes rufinotum*, *K. banksiae*; *Ceratokalotermes spoliator*; *Glyptotermes tuberculatus*; *Bifiditermes condonensis*; *Cryptotermes primus*, *C. brevis*, *C. domesticus*, *C. dudleyi*, *C. cynocephalus*), and subterranean termites (*Schedorhinotermes intermedius intermedius*, *S. i. actuosus*, *S. i. breinli*, *S. i. seclusus*, *S. reticulatus*; *Heterotermes ferox*, *H. paradoxus*; *Coptotermes acinaciformis*, *C. frenchi*, *C. lacteus*, *C. raffrayi*; *Microcerotermes boreus*, *M. distinctus*, *M. implicadus*, *M. nervosus*, *M. turneri*; *Nasutitermes exitiosis*). A moderate pest risk potential was assigned to pine loopers (*Chlenias* spp.), endemic weevils (*Aesiotes* spp.), *Sphaeropsis sapinea*, and the Armillaria root rot fungi (*Armillaria hinnulea*, *A. luteobubalina*, *A. novae-zealandiae*, and *A. pallidula*).

When chips were considered as the commodity, the risk potentials dropped from high to moderate for the two bark beetles and the ambrosia beetles and dropped from high to low for the Sirex woodwasp and the dampwood, giant, drywood, and subterranean termites. The risk potentials for the Diplodia shoot blight pathogen and the Armillaria root rot fungi dropped from moderate to low for the chip commodity.

Several factors suggest that *Pinus* spp. logs or chips destined for export from Australia may be relatively free of most damaging organisms. There is an excellent working knowledge of forest insects and pathogens and the ability to recognize problem situations when they occur. Commercial pine plantations are generally well-managed for maximum production and closely monitored to detect and control damaging pests. However, pines from Australian plantations, depending on location, management intensity, and other factors, may have insects and microorganisms that could be of concern if introduced into the U.S.

For those organisms of concern that are associated with the *Pinus* species grown in Australia that were considered in this pest risk assessment, specific phytosanitary measures may be required to ensure the quarantine safety of proposed importations. Detailed examination and selection of appropriate phytosanitary measures to mitigate pest risk is the responsibility of APHIS and beyond the scope of this assessment.

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CHAPTER 1. INTRODUCTION

BACKGROUND

There is an increasing interest in import-ing large volumes of unmanufactured wood articles into the United States from abroad. The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) is the government agency charged with preventing the introduction of exotic pests on plant material brought into the United States via international commerce. The USDA Forest Service (FS) has provided assistance to APHIS in conducting pest risk assessments of the importation of logs from Russia (USDA Forest Service 1991), New Zealand (USDA Forest Service 1992), Chile (USDA Forest Service 1993), Mexico (Tkacz et al. 1998), South America (Kliejunas et al. 2001) and Australia (Kliejunas et al. 2003) ac-cording to a memorandum of understanding between the two agencies signed in February 1992.

In September 1995, the Chief of the Forest Service chartered the Wood Import Pest Risk Assessment and Mitigation Evaluation Team (WIPRAMET), made up of FS employees to provide a permanent source of technical assistance to APHIS in conducting pest risk assessments of exotic pests that may move with logs. In September 2002, WIPRAMET conducted a site visit to Australia as part of a pest risk assessment of 18 species of euca-lypts in Australia. Because a future request to conduct a pest risk assessment of pines (*Pinus* spp.) in Australia was anticipated, the Team also gathered information on that resource in Australia during the same visit.

STATEMENT OF PURPOSE

The specific objectives of this risk assessment of *Pinus* spp. in Australia are to

- identify the potential pest organisms that may be introduced with imported un-processed *Pinus* spp. logs and chips from Australia (the baseline for this pest risk assessment is raw, unprocessed logs of *Pinus* species growing in Australia, with subsequent consideration of the effect of chipping on potential pest organisms),

- assess the potential for introduction (entry and establishment) in the United States of selected representative Austra-lian pests of the *Pinus* species, and

- estimate the potential economic and environmental impacts these pests may have on forest resources and urban trees if established in the United States.

SCOPE OF ASSESSMENT

This risk assessment estimates the likelihood that exotic pests will be introduced into the United States as a direct result of the impor-tation of unprocessed *Pinus* spp. logs and chips from Australia. Site visits by the team and APHIS were made to Queensland, New South Wales, Tasmania, South Australia, Vic-toria, and Western Australia (see Appendix A), where the preponderance of pine plantations and eucalypt forests in Australia occur (see Chapter 2). As mentioned, information on the pine resource at each location was noted as well. Pests addressed in this report are phytophagous insects and plant pathogens. Major emphasis is placed on pests with the potential to be transported on, in, or with unprocessed pine logs and chips destined for

export from Australia to the United States. This assessment also estimates the economic and environmental impact of the more potentially destructive organisms if introduced into the United States.

This risk assessment is developed without regard to available mitigation measures. Once the potential risks are identified, suitable mitigation measures may be formulated, if needed, to reduce the likelihood that destructive pests will be introduced into the United States on pine logs and chips from Australia. The prescription of mitigation measures, however, is beyond the scope of this assessment and is the responsibility of APHIS.

PEST RISK ASSESSMENT PROCESS

International plant protection organizations (for example, North American Plant Protection Organization [NAPPO] and the International Plant Protection Convention [IPPC] of the Food and Agriculture Organization of the United Nations [FAO]) provide guidance for conducting pest risk analyses. Further guidance pertinent to U.S. wood importation is contained in Title 7, CFR 319.40-11. This risk assessment conforms to the standards for plant pest risk assessments as described therein. The general process is as follows:

1. COLLECT COMMODITY
      INFORMATION

   • Evaluate permit applications and other sources for information describing the regulated article and the origin, processing, treatment, and handling of the regulated article—namely *Pinus* spp. logs and chips from Australia.

   • Evaluate data from United States and foreign countries on the history of plant

pest interceptions or introductions associated with logs and chips of *Pinus* spp. from Australia.

2. CATALOG PESTS OF CONCERN

   • Determine what plant pests or potential plant pests are associated with pine logs and chips in Australia. A plant pest that meets one of the following categories is a quarantine pest according to Title 7, CFR 319.40-11 and will be further evaluated:

      Category 1—Nonindigenous plant pest not present in the United States;

      Category 2—Nonindigenous plant pest, present in the United States and capable of further dissemination in the United States;

      Category 3—Nonindigenous plant pest that is present in the United States and has reached probable limits of its ecological range, but differs genetically (for example, as biotypes, pathovars, or strains) from the plant pest in the United States in a way that demonstrates a potential for greater damage in the United States;

      Category 4—Native species of the United States that has reached probable limits of its ecological range, but differs genetically from the plant pest in the United States in a way that demonstrates a potential for greater damage in the United States;

      Category 5—Nonindigenous or native plant pest capable of vectoring another plant pest that meets one of the above criteria.

In addition to these criteria for quarantine pests as specified in the log import regulations, WIPRAMET determined that a broader definition of genetic variation was needed for Category 4. The definition of this category was expanded to include native species that have reached the probable limits of their range but *may* differ in their capacity for causing damage based on the genetic variability exhibited by the species (Category 4a). There are uncertainties and unknowns about the genetic variability and damage potential of many pest organisms in forest ecosystems, because of these unanswered questions, the team was cautious in its assessments and included additional pests of concern not considered under the requirements of the log import regulations. For definition of Category 2, the team added native organisms with limited distributions within the United States but capable of further dissemination (Category 2a); some of these organisms may occupy a limited distribution only because they have not been afforded the opportunity to exploit additional environments.

3. DETERMINE WHICH OF THE PESTS OF CONCERN TO ASSESS

- Group identified pests of concern according to cataloging criteria by location on host (such as foliage–branches, bark–cambium, sapwood, or heartwood).

- Evaluate the plant pests in each location on the host according to pest risk, based on the available biological information and demonstrated or potential plant pest importance.

- Conduct individual pest risk assessments (IPRAs) for the pests of concern. Identify any quarantine plant pests for which plant pest risk assessments have been

previously performed in accordance with 7 CFR 319.40-11 and determine their applicability to the proposed importation from Australia. Pests with similar biology and that attack similar plant parts were evaluated in the same IPRA because they would react similarly to the same mitigation measures. The lack of biological information on any given insect or pathogen should not be equated with low risk (USDA Forest Service 1993). By necessity, pest risk assessments focus on those organisms for which biological information is available. By developing detailed assessments for known pests that inhabit different locations on imported logs (for example, on the surface of the bark, within the bark, and deep within the wood), effective mitigation measures can subsequently be developed to eliminate the known organisms and any similar unknown ones that inhabit the same niches.

4. EVALUATE LIKELIHOOD OF INTRODUCTION AND CONSEQUENCES OF INTRODUCTION FOR EACH IPRA

- Assign a risk value (high, moderate, or low) for each of seven elements.

Risk value is based on available biological information and subjective judgment of the assessment team. The seven elements and the rating criteria used to determine risk value for each element are described in Orr et al. (1993) and are listed in the following sections. The individual rating criteria were developed by the team that prepared the draft solid wood packing material pest risk assessment (USDA Animal Plant Health Inspection Service and Forest Service 2000) to facilitate the assign-

ment of low, moderate, or high risk ratings to each of the seven elements. Those rating criteria were used by WIPRAMET in a previous pest risk assessment (Kliejunas et al. 2003) in an attempt to make the assignment of risk ratings more consistent, objective, and transparent.

The seven elements are organized into two parts: likelihood of introduction and consequences of introduction (Orr et al. 1993). Each element in the assessment has different critical components, the combination of which is used to determine rating levels, and each element is assigned a certainty code (see Table 1). Rating criteria serve as guidelines for assigning values of high, moderate, or low to make up the final assessment of pest risk potential.

The resulting risk value for an element may be modified based upon knowledge of important biological characteristics not addressed by the criteria following each element. If scientific information is lacking for a criterion

Table 1—Description of certainty codes used with specific elements in the individual pest risk assessment process.

Certainty code	Symbol
Very certain	VC
Reasonably certain	RC
Moderately certain	MC
Reasonably uncertain	RU
Very uncertain	VU

Source: Orr et al. 1993.

for a particular organism, an evaluation of the criterion's appropriateness may be made based upon characteristics of closely related organisms. Organism complexes, such as an insect vector and associated pathogen, are to

be rated as a unit; therefore, the term "organism" as used herein may pertain to a complex of concern.

Likelihood of Introduction

In this section, the elements pertain to estimating the likelihood that the pest will enter, colonize, and spread in the United States. Exotic organisms are considered established once they have formed a self-sustaining, free-living population at a given location (U.S. Congress Office of Technology Assessment 1993).

Element 1. Pest with host-commodity at origin potential: likelihood of the plant pest being on, with, or in pine logs and/or chips at the time of importation. The affiliation of the pest with the host or commodity, both temporally and spatially, is critical to this element.

High risk = Criterion *a* applies, or five or more of criteria *b* through *h* apply.

Moderate risk = Criterion *a* does not apply, and two to four of criteria *b* through *h* apply.

Low risk = Criterion *a* does not apply, and one or none of criteria *b* through *h* apply.

Rating criteria:
a. Organism has been repeatedly intercepted at ports of entry in association with host materials.

b. Organism has capability for large-scale population increases.

c. Populations of organism are widely distributed throughout range of host(s).

d. Organism has multiple or overlapping generations per year or an extended period (several months or more) of colonization activity, thereby having capability to infest or infect new host material throughout at least one quarter of a year.

e. One or more stages of the organism may typically survive in the plant host for an extended period of time.

f. Organism has active, directed host searching capability or is vectored by such an organism. Colonization activity may be directed by attraction to host volatiles, pheromones, or lights. Organism may be generally associated with recently cut or damaged host material.

g. Organism has wide host range, or primary plant hosts are widely distributed in several regions of the world.

h. Organism is unlikely to be dislodged from host or destroyed during standard harvesting and handling operations.

Element 2. Entry potential: likelihood of the plant pest surviving in transit and entering the United States undetected. Important components of this element include the pest's ability to survive transport, which includes such things as the life stage and number of individuals expected to be present in or on the logs, chips, or transport vehicles.

High risk = Criterion *a* applies, or two or more of criteria *b* through *d* apply.

Moderate risk = Criterion a does not apply, and one of criteria *b* through *d* applies.

Low risk = None of the following four criteria apply.

Rating criteria:

a. Multiple interceptions of live specimens of organism have been made at ports of entry in association with host materials.

b. One or more stages of the organism are likely to survive in the plant host during transportation.

c. Organism is protected within host material or is unlikely to be dislodged from host or destroyed during standard handling and shipping operations.

d. Organism is difficult to detect (for example, concealment within host material, small size of organism, cryptic nature of organism, random distribution of organism in, on, or associated with host material).

Element 3. Colonization potential: likelihood that the plant pest will successfully colonize once it has entered the United States. Some characteristics of this element include the number and life stage of the pest translocated, host specificity, and likelihood of encountering a suitable environment in which the pest can reproduce.

High risk = Criterion *a* applies, or criterion *b* and two or more of criteria *c* through *e* apply.

Moderate risk = Criterion *a* does not apply; criterion *b* applies, or two or more of criteria *c* through *e* apply.

Low risk = Criteria *a* and *b* do not apply; none or only one of criteria *c* through *e* apply.

Rating criteria:

a. Organism has successfully established in location(s) outside its native distribution.

b. Suitable climatic conditions and suitable host material coincide with ports of entry or major destinations.

c. Organism has demonstrated ability to utilize new hosts.

d. Organism has active, directed host-searching capability or is vectored by an organism with directed host-searching capability.

e. Organism has high inoculum potential or high likelihood of reproducing after entry.

Element 4. Spread potential: likelihood of the plant pest spreading beyond any colonized area. Factors to consider include the pest's ability for natural dispersal, the pest's ability to use human activity for dispersal, the pest's ability to develop races or strains, the distribution and abundance of suitable hosts, and the estimated range of probable spread.

High risk = Five or more of the following eight criteria apply.
Moderate risk = Two to four of the following eight criteria apply.
Low risk = One or none of the following eight criteria apply.

Rating criteria:

a. Organism is capable of dispersing more than several kilometers per year through its own movement or by abiotic factors (such as wind, water, or vectors).

b. Organism has demonstrated ability for redistribution through human-assisted transport.

c. Organism has a high reproductive potential.

d. Potential hosts have contiguous distribution.

e. Newly established populations may go undetected for many years due to cryptic nature, concealed activity, slow development of damage symptoms, or misdiagnosis.

f. Eradication techniques are unknown, infeasible, or expected to be ineffective.

g. Organism has broad host range.

h. Organism has potential to be a more efficient vector of a native or introduced pest.

Consequences of Introduction

In this section, the elements pertain to estimating the potential consequences if the pest were to become established in the United States.

Element 5. Economic damage potential: estimate of the potential economic impact if the pest were to become established. Factors to consider include economic importance of hosts, crop loss, and effects on subsidiary industries, and availability of eradication or control methods.

High risk = Four or more of the following six criteria apply.
Moderate risk = Two or three of the following six criteria apply.
Low risk = One or none of the following six criteria apply.

Rating criteria:

   a. Organism attacks hosts or products that have significant commercial value (such as timber, pulp, wood products, wooden structures, Christmas trees, fruit or nut trees, syrup-producing trees, etc.).

   b. Organism directly causes tree mortality or predisposes host to mortality by other organisms.

   c. Damage by organism causes a decrease in value of the host affected—for instance, by lowering its market price; increasing cost of production, maintenance, or mitigation; or reducing value of property where it is located.

   d. Organism may cause loss of markets (foreign or domestic) due to presence of pests and quarantine-significant status.

   e. Organism has demonstrated ability to develop more virulent strains or damaging biotypes.

   f. No known control measures exist.

Element 6. Environmental damage potential: estimate of the potential environmental impact if the pest were to become established in the United States. Factors to consider include potential for ecosystem destabilization, reduction in biodiversity, reduction or elimination of keystone species, reduction or elimination of endangered or threatened species, and nontarget effects of control measures.

   High risk = Criterion *a* or *b* applies, or two or more of criteria *c* through *f* apply.

   Moderate risk = One of criteria *c* through *f* applies, and neither criterion *a* nor *b* applies.

   Low risk = None of the following six criteria apply.

Rating criteria:

   a. Organism is expected to cause significant direct environmental effects, such as extensive ecological disruption or large-scale reduction of biodiversity.

   b. Organism is expected to have direct impacts on species listed by federal or state agencies as endangered, threatened, or candidate. An example would be feeding on a listed plant species.

   c. Organism is expected to have indirect impacts on species listed by federal or state agencies as endangered, threatened, or candidate. This may include disruption of sensitive or critical habitat.

   d. Organism may attack a host with limited natural distribution.

   e. Introduction of the organism would probably result in control or eradication programs that may have potential adverse environmental effects.

   f. Organism has demonstrated ability to develop more virulent strains or damaging biotypes.

Element 7. Social and political considerations: estimate of the impact from social and/or political influences, including the potential for aesthetic damage, consumer concerns, and implications for domestic and international trade.

High risk = Two or more of the following four criteria apply.

Moderate risk = One of the following four criteria applies.

Low risk = None of the following four criteria apply.

Rating criteria:

a. Damage by organism would probably result in public concerns (for example, aesthetic or recreational concerns, or concern about urban plantings).

b. Presence of organism would likely have domestic trade implications.

c. Presence of organism would likely interfere with or burden domestic interstate commerce, trade, or traffic.

d. Known effective control measures are likely to have limited acceptance.

5. ESTIMATE UNMITIGATED PEST RISK POTENTIAL

The assessment team developed an estimate of the unmitigated plant pest risk for each individual pest risk assessment based on the compilation of the risk values for the seven risk elements. The method for compilation is presented in Orr et al. (1993).

- Determine the likelihood of introduction. The overall risk rating for the likelihood of introduction acquires the same rank as the single element with the lowest rating.

- Determine the consequences of introduction. Table 2 presents a method for ascertaining consequences of introduction for a specific pest organism or group of organisms with similar habits based on the individual ratings for economic and environmental damage potentials and social and political considerations.

- Determine the pest risk potential. The pest risk potential for each IPRA is determined based on the ratings for likelihood of introduction and consequences of introduction (Table 3).

For this assessment, the team considered pine logs and pine chips as two separate commodities, and a separate pest risk potential was estimated for each. Because the rating for Element 1 (the likelihood of the pest being on, with,

Table 2—Method for estimating consequences of introduction for an individual pest risk assessment[a].

Economic damage potential	Environmental damage potential	Social and political considerations	Consequences of introduction
H	L, M, or H	L, M, or H	H
L, M, or H	H	L, M, or H	H
M	M	L, M, or H	M
M	L	L, M, or H	M
L	M	L, M, or H	M
L	L	M or H	M
L	L	L	L

[a] L = low; M = moderate; H = high.

Source: Orr et al. 1993.

Table 3—Method for determining pest risk potential[a].

Likelihood of introduction [b]	Consequences of introduction	Pest risk potential
H	H	H
M	H	H
L	H	M or L [c]
H	M	H
M	M	M
L	M	M or L [c]
H	L	M
M	L	M
L	L	L

[a]L = low; M = moderate; H = high.

[b]The overall risk rating for the likelihood of introduction acquires the same rank as the single element with the lowest risk rating.

[c]If two or more of the single elements that determine likelihood of introduction are low, pest risk potential is considered low, rather than moderate, for this assessment.

Source: Orr et al. 1993.

or in the commodity at the time of importation) and for Element 2 (likelihood of the pest surviving in transit and entering the United States undetected) may change depending on whether the commodity is logs or chips, separate ratings for each of these two elements were estimated. Any differences in rating for the two elements based on commodity was then reflected in separate pest risk potentials for logs and for chips.

Outreach

In an effort to gather information pertinent to the pest risk assessment, WIPRAMET contacted scientists and specialists in the fields of forestry, forest entomology, forest pathology and the timber industry throughout the United States, Australia, Canada, England, France, New Zealand, and the Republic of South Africa. A preliminary list of poten-

tial organisms of concern was compiled and mailed to individuals for review. Suggested revisions to the list were incorporated into the final list prepared by WIPRAMET.

Site Visits

Site visits to the subject countries were an integral part of previous pest risk assessments. Teams of FS and APHIS specialists traveled to Russia (USDA Forest Service 1991), New Zealand (USDA Forest Service 1992), Chile (USDA Forest Service 1993), Mexico (Tkacz et al. 1998), and South America (Kliejunas et al. 2001) while working on pest risk assessments of those countries. Those site visits allowed the assessment teams to meet with local agricultural, quarantine, and forestry officials and entomologists, pathologists, and forest industry representatives to gather information on the proposed importation.

The teams also visited harvest areas, inspected processing plants and ports, viewed pest problems in plantations and forests, and evaluated mitigation procedures. The site visits allowed assessment teams to gather information that is not readily available in the literature and to verify pest risk assessments.

For this pest risk assessment, eight members of WIPRAMET and two APHIS officials conducted a site visit to Australia from September 12 to September 28, 2001. The entire team met in Canberra with various Australian officials from September 12 through September 14. The team then split into three sub-teams or groups, with one group traveling to Queensland and New South Wales, the second group to Victoria and Western Australia, and the third group to Tasmania and South Australia. In addition to eucalypt plantations and eucalypt natural forests, the sub-teams also looked at *Pinus radiata* and other *Pinus* spp. plantations in anticipation of a future pest risk assessment of *Pinus* spp. The team reconvened in Canberra September 27 for a closeout session with Australian officials. See Appendix A for the trip report.

Resources at Risk

The commodity being assessed for its potential to introduce plant pests into the United States is unprocessed logs and woodchips of *Pinus* spp. being grown in Australia. Therefore, the domestic resources at risk include, but may not be limited to, the genus *Pinus* and related species. The nature of the impacts of concern (e.g., mortality or reduced yield) and the susceptible hosts (*Pinus* or non-*Pinus*) are pest-specific and are addressed by the individual pest risk assessments.

The forests of the United States cover in excess of 295 million hectares, varying from sparse noncommercial forests of the interior West to the highly productive forests of the Pacific Coast and the South, and from pure hardwoods forests to multispecies mixtures (USDA Forest Service 1990). Log and chip importation of *Pinus* spp. from Australia could have serious adverse impacts on the economic and ecological value of these forests if destructive tree pests were introduced with the logs or chips. Because of the possibility of pine logs and chips from Australia being imported to any region of the United States, WIPRAMET has chosen to consider the forest resources throughout the United States as being at risk from pest establishment. Although this risk assessment generally used specific examples from limited regions when discussing impacts associated with introduced pests, we recognize that forests throughout the United States are potentially at risk, and that, in addition to economic values, other forest aspects (aesthetic, recreational, and ecological) are also important.

In addition to the extensive natural stands of conifers and hardwoods in the United States, there is a very sizable industry devoted to production of ornamentals and Christmas trees that could be affected by introduced pests. The potential impact on trees with limited range or genetic variability, as well as impacts on trees in the urban environment, also could be significant.

Descriptions of the dominant tree resources at risk within various regions of the country follow. More detailed descriptions of these regions can be found in USDA Forest Service (1990) and USDA APHIS (1994).

Eastern deciduous forest region. This region, which encompasses the Mid-Atlantic states, the Northeast, and parts of the Southeast, includes oak (*Quercus*)-pine (*Pinus*)-hickory (*Carya*), oak-hickory, sugar maple (*Acer saccharum* Marsh.)-beech (*Fagus grandifolia* Ehrh.), hemlock (*Tsuga*), white pine (*Pinus strobus* Engelm.), and spruce (*Picea*) forests, and northern hardwood forests.

Southeast region. The southeastern coastal plain region extends from the Texas Gulf Coast to southern New Jersey, including the lower Mississippi River Basin. Oak, pine, and mixed oak-pine forests are characteristic.

North Central and Great Plains regions. The predominant forest types of these regions include aspen (*Populus*)-birch (*Betula*), oak hickory, northern hardwoods [maple (*Acer*), beech (*Fagus*), and basswood (*Tilia*)], lowland hardwoods [elm (*Ulmus*), cottonwood (*Populus*), oak, and maple], lowland conifers [black spruce (*Picea mariana* (Mill.) B.S.P.), northern white cedar (*Thuja occidentalis* L.), and larch (*Larix*)], and mixed pines.

Pacific Northwest region. Extending from mid-coastal California to southern Alaska, this region is characterized by predominantly mixed conifer forest composed of pines, true fir (*Abies*), hemlock, and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Pure pine forests occur in the southern Cascades and on the easern slop of the Sierra Nevada. Other softwoods, including western larch (*Larix occidentalis* Nutt.), western redcedar (*Thuja plicata* Donn ex. D. Don), redwood (*Sequoia sempervirens*

(D. Don) Endl.), and other minor species occur in localized areas.

Pacific Southwest region. Although mostly desert and shrub land, the area comprising mid-coastal California south and east into the desert of the Southwest contains several pine species, including *Pinus radiata*, Douglas-fir, and incense-cedar (*Libocedrus decurrens* Torr.).

Rocky Mountain region. At lower elevations, dominant trees are broad-leaved deciduous species. Higher elevations are characterized by ponderosa pine (*Pinus ponderosa* Dougl. Ex. Laws var *scopulorum*) woodlands, mixed pine-oak woodlands, and Douglas-fir and spruce-fir-hemlock forests.

CHAPTER 2. *PINUS* RESOURCES OF AUSTRALIA

PINUS PLANTATIONS IN AUSTRALIA

Pinus is a genus exotic to Australia. It was first introduced as a plantation tree in 1876 at Bundaleer, north of Adelaide. Five pine species were noted as promising in this planting, including *P. radiata* D. Don. In 1880, the first commercial plantation of *P. radiata* was established in Victoria. Later, additional plantations of *P. radiata* and other *Pinus* species were planted in other states of Australia. This included species of *P. elliottii* Engelm. var. *elliottii*, *P. taeda* L., and *P. caribaea* var. *hondurensis.* The planting of *Pinus* increased dramatically after the Second World War as plantations were established to meet future pulpwood demand. Legislation in the 1960s encouraged the development of State-owned plantations from 1967 to 1977 (Australian Academy of Technological Sciences and Engineering 1988).

Australia has approximately 1.7 million hectares (4.2 million acres) of plantations, of which 1,000,642 hectares (2,472,636 acres) (58 percent) are softwood species, mostly *P. radiata,* and 715,531 hectares (1,768,113 acres) (42 percent) are hardwood species, mostly eucalypts (National Forest Inventory 2005). The area of conifer plantations varies by state (Fig. 1). More than 80 percent of plantation wood is domestically processed. Plantation timber exceeds timber from native forests in volume and value and represents about two-thirds of all forest products.

Australia's total plantation inventory has been increasing most every year, including hardwood and softwood species (National Forest Inventory 2005). Hardwood species have made up the bulk of that increase, but the area of softwoods exceeded one million hectares in 2004. Most of the softwoods are various species of *Pinus*. A minor amount of area is planted with native *Araucaria* species. The area of softwoods by state and territory from 1999 to 2004 is identified in Table 4. The largest area of softwood plantations is in New South Wales, followed by Victoria and Queensland (Figure 1). These three states comprise 67 percent of the national plantation

Table 4—Area (hectares) of softwood plantations in Australian states and territories from 1999 to 2004[a].

State	1999	2000	2001	2002	2003	2004
Australian Capital Territory	15,269	14,585	14,516	15,713	5,264	5,363
New South Wales	246,934	270,672	269,536	270,467	280,251	287,302
Northern Territory	5,235	5,235	3,817	3,817	3,817	3,817
Queensland	185,555	178,620	181,303	181,598	181,088	180,158
South Australia	106,153	113,871	114,670	116,768	120,493	124,313
Tasmania	75,412	75,630	75,313	78,162	76,104	74,420
Victoria	219,197	215,110	217,253	217,285	211,961	214,874
Western Australia	94,500	98,441	102,559	104,054	109,246	110,395
Total	948,255	972,164	978,967	987,864	988,223	1,000,642

[a]Source: National Plantation Inventory Australia, Bureau of Rural Sciences, Canberra.
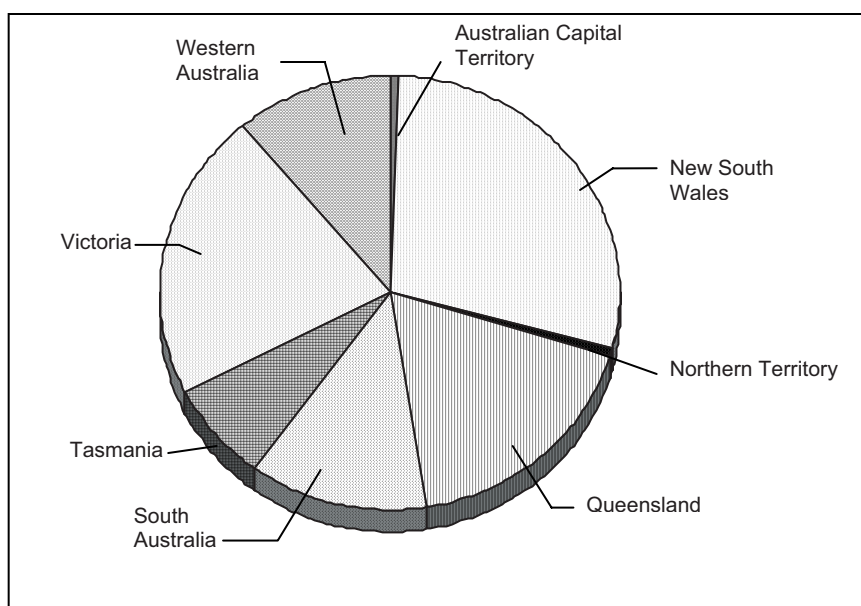
Figure 1—Area of Softwood Plantations by State in Australia – 2004.
Source: National Forest Inventory 2005. National Plantation
Inventory 2005, Bureau of Rural Sciences, Canberra.

total of softwoods. The decline in area in Australian Capital Territory and Victoria in 2003 is a result of plantations burned in wildfires that year that had not been replanted. Overall, Australia has increased its area of softwood plantations during the past six years by 5.5 percent. Most of this increase has been in New South Wales (16 percent), South Australia (17 percent), and Western Australia (17 percent).

In October 1997, the Commonwealth, state governments, and the Australian timber industry launched the "Plantations for Australia: 2020 Vision," which aims to increase the Australian area in plantations to 3 million hectares (7.4 million acres) by 2020. Achieving this objective will require an average planting of around 80,000 hectares (197,684 acres) per year. This goal is very ambitious, as the average annual planting during the peak plantation period of the 1970s and early to mid-1980s was 30,000 hectares (74,132 acres) (Foreign Agriculture Service 1999).

Early use of plantation pine was for lumber. Following the Second World War, pines were increasingly planted as a future source of pulpwood. Currently, Australian plantations (hardwoods and softwoods) supply more than 50 percent of the domestic demand. However, Australia's imports of forest products were more than double its exports in 1999-2000. Most of the imports (70 percent) were pulp and paper. This trade deficit is expected to continue unless manufacturing capacity is increased in pulp and paper manufacturing.

Australia exports both manufactured wood products and raw products, including logs and wood chips. The primary recipient of wood chips from Australia is Japan. Australia exported 848.5 kilotonnes of coniferous wood chips to Japan in 2001-02; 994.8 kilotonnes in 2002-03; and 1,098.8 kilotonnes in 2003-04 (ABARE 2005). An additional 0.1 kilotonnes were exported to other countries in 2001-02. The largest exporting state for each of these three years was Victoria, followed by Queensland (Table 5).

Table 5—Annual exports of coniferous wood chips (kilotonnes) from Australia.

State	2001-02	2002-03	2003-04
New South Wales	5.4	0.0	0.0
Victoria	575.0	751.9	777.9
Queensland	244.7	235.3	308.4
South Australia	0.0	0.0	0.0
Western Australia	0.0	0.0	0.0
Tasmania	23.4	7.6	12.4
Northern Territory	0.0	0.0	0.0

Source: ABARE 2005.

GLOBAL SOFTWOOD MARKET, AUSTRALIAN SUPPLY

Australia is predominantly an import market for forest products, with the major exception of wood chips. The Australian Bureau of Agricultural and Resource Economics (ABARE) estimated that approximately 80 percent of Australian hardwood woodchips and 30 percent of softwood woodchips are exported. In 2004, exports of softwood chips and logs reached 1.7 million metric tons (UN Statistics Division). Woodchips, including softwood chips, have generally accounted for just over half the value of Australian forest product exports in the 1990s and reached a record $646 million in 1997-1998 (Australian Bureau of Agricultural and Resource Economics 1999). Japan took about 95 percent of the 3.9 million tons of wood chips exported in 1998-1999 (Foreign Agriculture Service 1999). Most Australian wood exports are destined for nations in the Asia-Pacific region, with the major markets being Japan ($600 million), New Zealand ($316 million), and other Asian countries (excluding Japan) ($312 million).

Australia's woodchip exports remained relatively stable from 1999-2000 through 2003-2004 (Fig. 2), with hardwood chips domi-
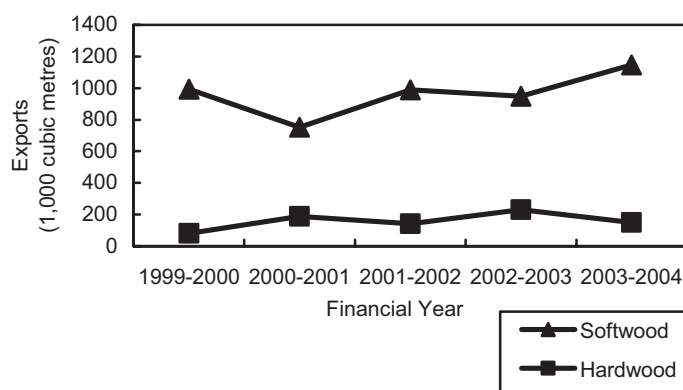
Figure 2—Export of Australian hardwood and softwood chips, 1999-2000 to 2003-2004.
Source: Australian Bureau of Agricultural and Resource Economics (ABARE) 2002 and 2005.

nating (ABARE 2002 and 2005). Australia's pulpwood supplies are expected to increase rapidly and peak in 2009 (Flynn and Shield 1999). Softwood log exports from Australia showed continued growth during the period 1999 to 2004 (Fig. 3). Hardwood log exports were considerably lower and stable. Exports of Australian forest products in 2003-2004 totaled Aus$2,055.6 million; this included Aus$185.7 million of round and sawn wood products, Aus$148.5 million in wood based panels, Aus$794.4 million of wood chips, and Aus$713.3 million of paper and paperboard (ABARE 2005).

CHARACTERISTICS OF THE PROPOSED IMPORTATION

APHIS has received written and verbal indication of interest to import *Pinus* logs and chips from Australia into the United States. The commodity proposed for import into the United States is wood chips, but could include unprocessed logs in the future. The chips would be expected to arrive by marine transport to any port of entry in the United States. The amount of *Pinus* commodities exported from Australia to the United States is unpredictable and will depend on, among other factors, market prices, currency values, and demand from other countries, especially Japan.

U.S. DEMAND FOR SOFTWOOD LOGS AND CHIPS

United States consumption of softwood timber products slowly increased during the 1990s following a drop to a low in 1991. This increase continued into the 21st century. Meanwhile, softwood production in the United States declined from its highs in the late 1980s and stabilized. The difference between consumption and production has been made up by increasing imports of softwood materials. The increase has been in manufactured wood products and softwood logs (Fig. 4). Most of the increased softwood timber product imports have come from Canada (93 percent of all sawn softwood imports), although Europe increased their share of the market (Howard 2002).

The strong United States housing market in 2001-2002 led to increases in domestic sawn softwood production, increases in imports, and decreases in exports of softwood materials. Most softwood logs are used for structural lumber and milled wood products, such as moldings, plywood, and doors.

Softwood chip imports have decreased through 2002 (Fig. 4). Softwood chips are mainly used for lower quality paper and paperboard, as well as composite wood products
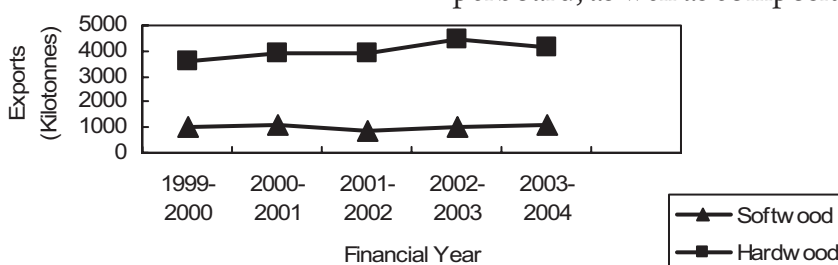
Figure 3—Export of Australian hardwood and softwood logs (including pulp logs), 1999-2000 to 2003-2004. Source: Australian Bureau of Agricultural and Resource Economics (ABARE) 2002 and 2005.
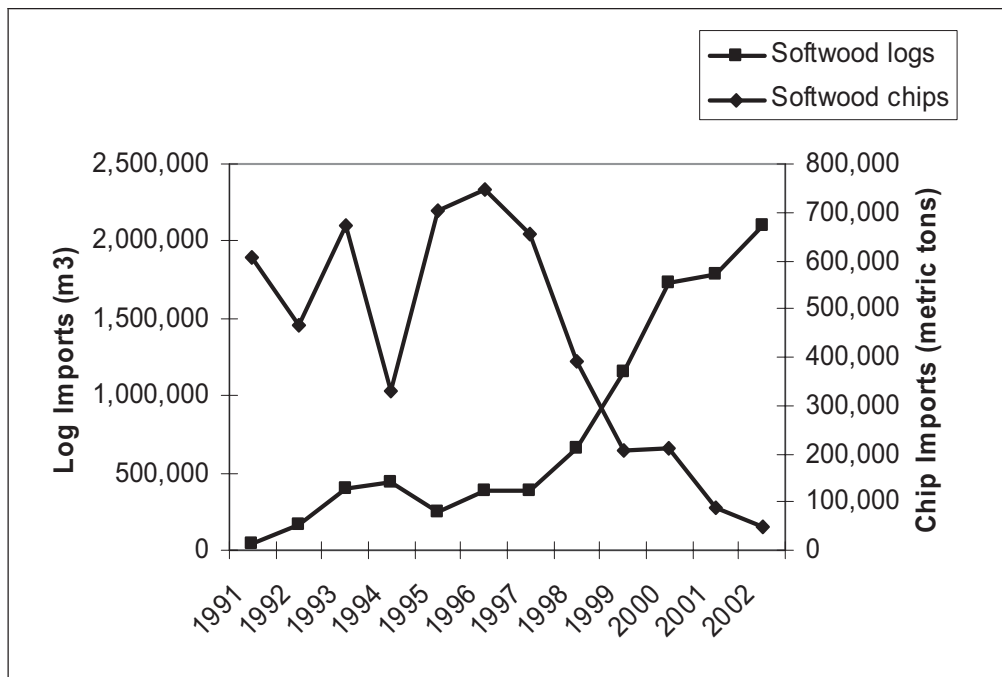
Figure 4—Importation of softwood logs and chips into the United States, 1991-2002. Source: USDA Foreign Agricultural Service 2003.

(such as oriented strandboard, particleboard, and medium density fiberboard). Other than oriented strandboard, the production of these products declined in the early 21st century (Howard 2002).

Even though paper and paper product production declined, the United States is still the largest consumer of these products in the world. The United States continued to be the largest single exporting country of softwood chips in the world during the past decade (Fig. 5). The second largest exporter was Australia. New Zealand was the largest exporter of softwood logs, with the United States and Australia a distant third and tenth, respectively (Fig. 6).

Since peaking in 1995, total pulpwood production and pulp mill consumption have declined in the United States (Fig. 7) (Howard 2001). Total pulpwood consumption in United States mills of 86.7 million cords (314.2 million cubic meters) in 1999 was met by approximately 82.0 million cords (297.2 million cubic meters) of

domestic production plus net imports. For the past several years, the United States paper industry has been characterized by overcapacity and low commodity prices. Declining prices have led to contraction in both softwood and hardwood pulp demand. Between 1992 and 1997, the number of pulp mill establishments [Standard Industrial Classification (SIC) 2611] declined by 13 percent (U.S. Census Bureau 2000), and eight of the nation's 186 pulp mills shut down in 1999 (Howard 2001). Since then, further erosion in pulpwood demand has continued.

LOCATION OF U.S. PULP MILLS AND WOODCHIP PORT FACILITIES

The location of United States pulp mills and woodchip port facilities provides some indication of the most likely exposure routes associated with potential *Pinus* pulpwood and woodchip imports. Pulp mills are lo-
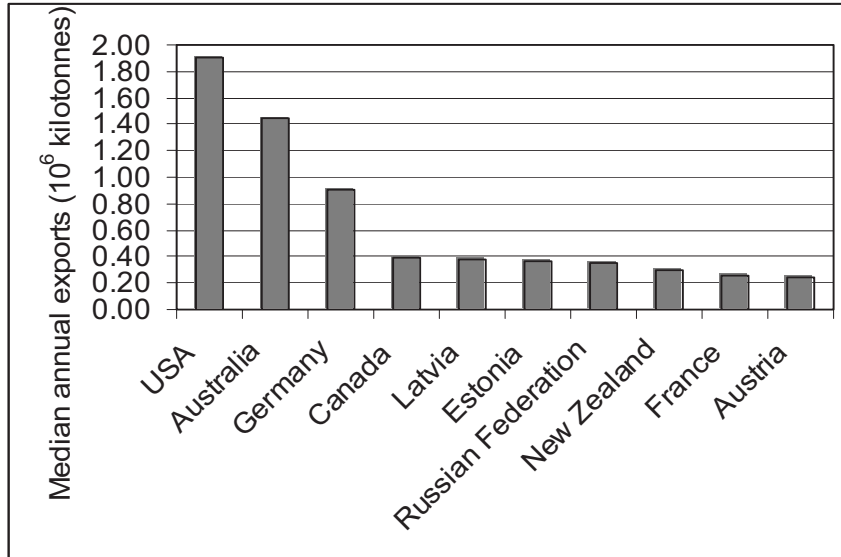
Figure 5—Top ten countries exporting softwood chips 1996-2004.
Source: United Nations Statistics Division.
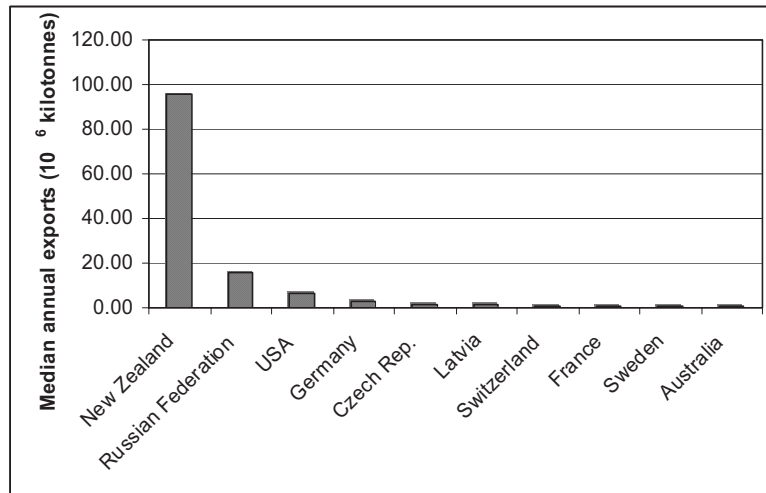
Figure 6—Top ten countries exporting softwood logs, 1996-2004.
Source: United Nations Statistics Division.
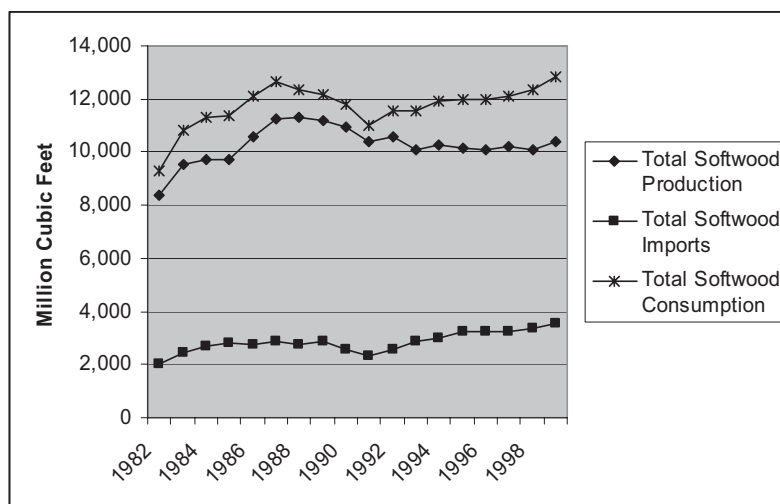
Figure 7—Production, Consumption, and Imports of Softwood Timber Products in the United States, 1982-1999.
Source: Howard 2001.

cated primarily in regions of the country where pulpwood is harvested. Traditionally, pulpwood production has been concentrated in the southern United States. In 1996, nine of the top ten pulpwood producing states were in the southern region (Johnson 2001). Southern mills had more than 70 percent of the U.S. pulping capacity in 2003 (Johnson and Steppleton 2005), when the highest concentration of softwood-utilizing pulp mills was in Alabama and Georgia (Johnson and Steppleton 2005).

Woodchip export facilities generally have the infrastructure to accommodate imports as well. As of 1999, southern woodchip export facilities included Beaumont, Texas; Lake Charles, Louisiana; Reserve, Louisiana; Convent, Louisiana; Mobile, Alabama; Savannah, Georgia; Wilmington, South Carolina; and Morehead City, North Carolina (Neilson and Flynn 1999). Although the Pacific Coastal region (California, Oregon, Washington, and Alaska) has a substantial pulp industry, most of the wood raw material is chips produced as byproduct from timber and lumber produc-

tion. Oregon leads the Pacific Coastal region in pulpwood production (Johnson 2001). As of 1999, United States Pacific Coastal woodchip export facilities included Homer, Alaska; Port Angeles, Washington; Tacoma, Washington; Coos Bay, Oregon; Eureka, California; and Sacramento, California (Neilson and Flynn 1999).

PREVIOUS INTERCEPTIONS OF QUARANTINE ORGANISMS

A search of the APHIS PIN 309 database (Port Information Network) was made for *Pinus* materials imported from Australia and New Zealand. Few records were identified. The organisms identified as having been intercepted at U.S. ports from Australian and New Zealand *Pinus* material are listed in Table 6. Although this PRA does not address commodities from New Zealand, that country has similar conditions to Australia, and it was believed information from this source might provide further information and insights.

Table 6—Organisms recovered at U.S. ports from imported Pinus unmanufactured wood products shipped from Australia and New Zealand (USDA APHIS PIN 309).

Host	Origin	Pest	Date
Pinus radiata	Australia	*Pineus* sp.	2003
Pinus sp. (fruit)	Australia	Pseudococcidae, species of	1996
Pinus sp. (fruit)	Australia	*Mycosphaerella* sp.	2000
Pinus sp. (seed)	Australia	Lygaeoidea, species of	1985
Pinus sp. (seed)	Australia	Pentatomidae, species of	1995
Pinus sp.	Australia	*Pissodes* sp.	1993
Pinus ponderosa	New Zealand	Scolytidae, species of	1996
Pinus radiata	New Zealand	*Hylurgus* sp.	1991
Pinus radiata	New Zealand	*Monochamus* sp.	1997
Pinus radiata	New Zealand	Scolytidae, species of	1991
Pinus radiata (fruit)	New Zealand	*Phyllosticta* sp.	1999

In addition to the search of the PIN 309 database, Oregon Department of Agriculture provided information from evaluations of imported *Pinus* lumber that was received in Oregon in 2000. Green, air-dried, and kiln-dried lumber shipments from Australia were examined and sampled for insects, fungi, bacteria, and nematodes from 18 different lots received during the year. A few insects, live and dead, and evidence of insect damage were discovered. The insects identified included mites, a Carabid beetle, Diptera larvae, *Brachypeplus* sp., a gall gnat, and a yellowjacket.

Isolations for fungi from the lumber identified several wood-decaying organisms, including *Phaeolus schweinitzii*, *Inonotus dryadeus*, *Fomitopsis pinicola*, *Bjerkandera adusta*, and *Coniophora puteana*. All of these are native to the forests of the United States. The identification of these fungi was based on cultural characteristics using Noble's key (Noble 1965). This key was developed using North American species of wood decay fungi. It is possible that similar fungi from other parts of the world may have the same characteristics, resulting in misidentification. Utilizing DNA techniques would provide a confirmation of actual species identification.

Other fungi isolated included cosmopolitan mold fungi and other saprophytes. Several genera with phytopathological members were recovered, but species identification was not made so it is uncertain if any pathogens were present. Searching for bacteria and nematodes, likewise, did not find any known pathogens.

Because most of the *Pinus* resource exported from Australia is shipped to Japan and Korea, inquiries were made with quarantine officials there. Japan requires quarantine inspection by MAFF (Ministry of Agriculture, Forestry and Fisheries of Japan) for both dry (logs and chips) and fresh (foliage) *Pinus*, but only fresh imports require certification from AQIS (Australian Quarantine and Inspection Service). Korea requires mandatory fumigation prior to import as a condition of entry. They do not have any interception records for this commodity. We were unable to obtain import interception records from Japan.

CHAPTER 3. INSECTS AND PATHOGENS POSING RISK

INTRODUCTION

The probability of pest introduction is determined by several related factors, including the likelihood of a pest traveling with and surviving on a shipment from the place of origin, the likelihood of a pest colonizing suitable hosts at the point of entry and along transport routes to processing sites, and the likelihood of subsequent pest spread to adjacent territories. Many insects and pathogens could be introduced on logs or chips of *Pinus* spp. from Australia into the United States. Because it would be impractical to analyze the risk of all of them, some form of selection was necessary. Selection was based on the likelihood of the pest being present on or in the logs or chips, and on their potential risk to resources in the United States. The pest risk assessment team compiled and assessed pertinent data using the methodology outlined in Pest Risk Assessment Process in Chapter 1 and as used in previous pest risk assessments (Kliejunas et al. 2001, Kliejunas et al. 2003, Tkacz et al. 1998, USDA Forest Service 1991, 1992, and 1993).

ANALYSIS PROCESS

The general analysis process used is explained in Chapter 1. For this risk assessment, information was collected from an array of sources on the organisms associated with *Pinus* species grown in Australia that have the potential to be exported commercially to the U.S. Lists of insects and pathogens that have been reported to inhabit the *Pinus* species in Australia were compiled from the literature, from information provided by Australian forest entomologists and pathologists, from information received from reviewers of a pre-liminary list prepared by the team, and from information described in Chapter 1. These organisms were catalogued in one of the categories of quarantine pests defined in the log import regulations (Title 7, CFR 319.40-11). The team broadened some of the categories to include a broader definition of genetic variation (Table 7). The organisms were also identified as to the part of the plant they affect: nursery seedlings, surface of foliage or bark, in or under the bark, and in the wood. From these lists, organisms were selected for further analysis. Organisms were selected from each of the plant parts affected (except for nursery seedlings). Organisms were selected because of the amount of damage they cause in Australia, the availability of information available on the organism, and the pathway they represent. For each organism selected, a thorough individual pest risk assessment was developed (as described previously in Chapter 1 under Pest Risk Assessment Process).

TABLES OF POTENTIAL INSECTS AND PATHOGENS OF CONCERN

The species of insects and pathogens associated with *Pinus* species in Australia and identified as potential pests of concern are presented in Tables 8 and 9. The lists include 104 insects and 10 pathogens. The organisms listed in Tables 8 and 9 are not meant to be a definitive or all-inclusive list, but are a result of literature searches and information provided by colleagues in Australia. In order for an organism to be listed in Table 8 or in Table 9, it must have been identified with one of the Australian *Pinus* hosts, either through the literature or through communication with Australian entomologists or pathologists.

Table 7—Pest categories and descriptions.

Category	Description
1	Nonindigenous plant pest not present in the United States.
2	Nonindigenous plant pest present in the United States and capable of further dissemination in the United States.
2a	Native plant pest of limited distribution in the United States but capable of further dissemination in the United States.
3	Nonindigenous plant pest present in the United States that has reached probable limits of its ecological range but differs genetically from the plant pest in the United States in a way that demonstrates a potential for greater damage potential in the United States.
4	Native species of the United States that has reached probable limits of its ecological range but differs genetically from the plant pest in the United States in a way that demonstrates a potential for greater damage potential in the United States.
4a	Native pest organisms that may differ in their capacity for causing damage, based on genetic variation exhibited by the species.
5	Nonindigenous or native plant pest that may be able to vector another plant pest that meets one of the above criteria

That host is listed in Table 8 or 9, as are any additional hosts known to harbor the insect or pathogen. Those insects or pathogens whose hosts are listed simply as "*Pinus* spp." are ones suspected of being associated with *Pinus* species in Australia, but where specific hosts are not definitively known. Bold type is used in Tables 8 and 9 to highlight the insects or pathogens treated in Individual Pest Risk Assessments (IPRAs). The tables represent a list of potential pests of concern, and do not represent, or judge, quarantine status of any of the organisms listed.

INDIVIDUAL PEST RISK ASSESSMENTS

Eleven IPRAs were prepared: nine dealing with insects and two with pathogens. The objective was to include in the IPRAs representative examples of insects and pathogens found on the bark, in the bark, and in the wood that would have the greatest potential risk to forests and other tree resources of the United States. The organizations team recognized that these might not be the only organisms associated with the *Pinus* species in Australia. They are, however, representative of the diversity of insects and pathogens that inhabit logs and chips. By necessity, the IPRAs focus on those insects and pathogens for which biological information is available. The assessments of risks associated with known organisms that inhabit a variety of niches on logs and chips will be used by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) to identify effective mitigation measures to eliminate both the known organisms and any similar heretofore-unknown organisms that inhabit the same niches. Summary tables of the IPRA results can be found in Chapter 4.

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Acropolitis ergophora Meyrick (Lepidoptera: Tortricidae)	NSW	*Pinus radiata*	X	X				1
Acropolitis rudisana (Walker) (Lepidoptera: Tortricidae)	NSW	*Pinus radiata*	X	X				1
Adoryphorus couloni (Burmeister) (Coleoptera: Scarabaeidae)	SA	*Pinus radiata, Eucalyptus* spp.	X					1
Aesiotes leucurus Pascoe (Coleoptera: Curculionidae)	QLD NSW	*Pinus radiata, P. halepensis*				X		1
Aesiotes notabilis Pascoe (Coleoptera: Curculionidae)	QLD NSW	*Pinus caribaea, P. elliottii, P. montezumae, P. taeda, Araucaria cunninghamii, A. bidwillii, Agathis palmerstonii, A. robusta*			X			1
Agrotis infusa (Boisduval) (Lepidoptera: Noctuidae)	VIC NSW SA	*Pinus radiata*	X					1
Agrotis munda Walker (Lepidoptera: Noctuidae)	NSW SA	*Pinus radiata*	X					1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Amasa truncatus (Erichson) (Coleoptera: Scolytidae)	NSW QLD SA TAS VIC (NZ)[c]	*Pinus radiata, Eucalyptus acmenioides, E. camaldulensis, E. piperita, E. propinqua, E. rostrata, E. saligna, Eucalyptus* spp., *Corymbia citriodora, C. maculata, Angophora intermedia*				X		1
Anthela nicothoe (Boisduval) (Lepidoptera: Anthelidae)	NSW	*Pinus radiata*		X				1
Arachnographa micrastrella (Meyrick) (Lepidoptera: Oechophoridae)	NSW QLD VIC	*Pinus radiata, P. elliottii, P. pinaster; Hakea sericea, Juniperus* sp.		X				1
Arhopalus (=Chryocephalus) syriacus Reitter (Coleoptera: Cerambycidae)	VIC	*Pinus radiata*				X		1
Austracris guttulosa (Walker) (Orthoptera: Acrididae)	SA	*Pinus radiata*	X					1
Bifiditermes condonensis (Hill) (Isoptera: Kalotermitidae)	NSW QLD SA VIC WA	***Eucalyptus*** spp., *Pinus* spp.				X	X	1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Bostrychopsis jesuita (Fabricius) (Coleoptera: Bostrichidae)	WA	*Eucalyptus marginata, Corymbia calophylla, C. maculata, Pinus pinaster, Melia azedarach, Grevillea robusta, Brachychiton populneus, Delonix regia*				X	X	1
Cacodacnus planicollis (Blackburn) (Coleoptera: Cerambycidae)	QLD SA VIC	*Pinus radiata*				X	X	1
Ceroplastes rubens Maskell (Homoptera: Coccidae)	QLD	*P. caribaea, P. taeda, Pinus* spp.		X				1
Chermes borneri (Ann.) (Homoptera: Adelgidae)	VIC	*Pinus radiata*		X				1
***Chlenias auctaria* Guenée (=*C. pachymela, C. pini*) (Lepidoptera: Geometridae)**	SA VIC	*Pinus radiata*		X				1
***Chlenias zonaea* Guest (Lepidoptera: Geometridae)**	TAS VIC	*Pinus* spp.		X				1
***Chlenias* spp. (Lepidoptera: Geometridae)**	NSW SA TAS VIC	*Pinus radiata, Pinus* spp*., Eucalyptus* spp*., Nothofagus* spp*., Cupressus* spp.	X	X				1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Chortoicetes terminifera (Walker) (Orthoptera: Acrididae)	SA VIC	*Pinus radiata*	X					1
Chrysolopus spectabilis Fabricius (Coleoptera: Curculionidae)	VIC	*Pinus radiata*		X				1
Clania tenuis Meyrick (Lepidoptera: Psychidae)	NSW	*Pinus radiata*		X				1
Coccus hesperidum Linnaeus (Hemiptera: Coccidae)	NSW	*Pinus radiata*		X				1
Coptotermes acinaciformis (Froggatt) (Isoptera: Rhinotermitidae)	NSW NT QLD SA VIC WA (NZ)	*Eucalyptus camaldulensis, E. grandis, E. pilularis, Eucalyptus* spp. *Pinus* spp.				X	X	1
Coptotermes acinaciformis raffrayi (Froggatt) (Isoptera: Rhinotermitidae)	WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Coptotermes frenchi Hill (Isoptera: Rhinotermitidae)	ACT NSW QLD SA VIC WA (NZ)	*Eucalyptus* spp., *Pinus* spp.				X	X	1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/Territory	Hosts	Seedlings in nursery	Foliage/branches	Bark/cambium	Sapwood	Heartwood	Pest Category[b]
Coptotermes lacteus (Froggatt) (Isoptera: Rhinotermitidae)	ACT NSW QLD VIC	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Cryptotermes brevis (Walker) (Isoptera: Kalotermitidae)	NSW	Seasoned hardwood and softwoods				X	X	2
Cryptotermes domesticus (Haviland) (Isoptera: Kalotermitidae)	ACT QLD	Seasoned hardwood and softwoods				X	X	1
Cryptotermes dudleyi Banks (Isoptera: Kalotermitidae)	QLD	Seasoned hardwood and softwoods				X	X	1
Cryptotermes cynocephalus Light (Isoptera: Kalotermitidae)	QLD	Seasoned hardwood and softwoods				X	X	1
Cryptotermes primus Hill (Isoptera: Kalotermitidae)	QLD NSW	Seasoned hardwood and softwoods				X	X	1
Digglesia australasiae (Fabricius) (Lepidoptera: Lasiocampidae)	NSW	*Pinus radiata*		X				1
Diphucephala colaspidoides Gyllenhal (Coleoptera: Scarabaeidae)	SA	*Pinus radiata*		X				1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/Territory	Hosts	Seedlings in nursery	Foliage/branches	Bark/cambium	Sapwood	Heartwood	Pest Category[b]
Ecrizothis terminalis Oken (Coleoptera: Curculionidae)	VIC	*Pinus radiata*		X				1
Ectropis excursaria Guenée (Lepidoptera: Geometridae)	SA	*Pinus radiata*		X				1
Epiphyas caryotis (Meyrick) (Lepidoptera: Tortricidae)	NSW	*Pinus radiata*		X				1
Epiphyas postvittana (Walker) (Lepidoptera: Tortricidae)	NSW SA VIC	*Pinus radiata*		X				1
***Ernobius molllis* Linnaeus (Coleoptera: Anobiidae)**	ACT NSW SA VIC WA	*Pinus radiata*, *Pinus* spp.			X	X		2
Erythroneura sp. (Homoptera: Cicadellidae)	ACT	*Pinus radiata*, *Larix* spp., *Quercus* spp., *Betula* spp.		X				1
Eulachnus thunbergii Wilson (Hemiptera: Aphididae)	QLD NSW	*Pinus caribea x elliottii*, *P. elliottii, P. muricata, P. patula, P. radiata, P. taeda, P. taiwanensis, Pinus* spp.		X				1
Euxoa radians (Guenée) (Lepidoptera: Noctuidae)	NSW	*Pinus radiata*	X					1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Glyptotermes tuberculatus Froggatt **(Isoptera: Kalotermitidae)**	NSW (NZ)	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Haploceros sphenotypa Turner (Lepidoptera: Geometridae)	NSW	*Pinus radiata*		X				1
Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae)	VIC	*Pinus radiata*	X					1
Helicoverpa punctigera (Wallengren) (Lepidoptera: Noctuidae)	QLD NSW WA	*Pinus radiata*, P. taeda	X	X				1
Heliothis punctigera Wallengren (Lepidoptera: Noctuidae)	NSW	*Pinus radiata*	X					1
Heliothrips haemorrhoidalis Bouché (Thysanoptera: Thripidae)	ACT NSW VIC	*Pinus radiata*, *Pseudotsuga menziesii*		X				2
Heteronyx obesus (Coleoptera: Scarabaeidae)	SA	*Pinus radiata*	X					1
Heteronyx sp. (Coleoptera: Scarabaeidae)	WA	*Pinus pinaster*	X					1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Heterotermes ferox (Froggatt) (Isoptera: Rhinotermitidae)	ACT NSW QLD SA VIC WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Heterotermes paradoxus (Froggatt) (Isoptera: Rhinotermitidae)	NT QLD WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Hyalarcta huebneri (Westwood) (Lepidoptera: Psychidae)		*Pinus radiata*		X				1
***Hylastes ater* Paykull (Coleoptera: Scolytidae)**	NSW SA TAS VIC	*Pinus radiata, Pinus canariensis, P. muricata, P. halepensis, P. pinaster, P. ponderosa, P. nigra, P. sylvestris, Pinus* spp.*, Pseudotsuga* spp.*, Larix* spp.*, Abies* spp.*, Picea* spp.	X		X			1
***Hylurgus ligniperda* (Fabricius) (Coleoptera: Scolytidae)**	NSW SA VIC	*Pinus radiata, P. canariensis, P. elliottii, P. halepensis, P. montezumae, P. nigra, P. patula, P. pinaster, P. pinea, P. strobus, Pinus* spp.			X			2
***Kalotermes banksiae* Hill (Isoptera: Kalotermitidae)**	SA VIC (NZ)	*Eucalyptus* spp.				X	X	1

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Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Kalotermes rufinotum Hill (Isoptera: Kalotermitidae)	NSW	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Lepidoscia arctiella (Walker) (Lepidoptera: Psychidae)	TAS	*Eucalyptus* spp., *P. inus radiata*		X				1
Lepispilus sulcicollis Boisduval (Coleoptera: Tenebrionidae)	VIC	*Pinus radiata*		X				1
Lichenaula sp. (Lepidoptera: Xyloryctidae)	VIC	*Pinus radiata*		X				1
Mastotermes darwiniensis Froggatt (Isoptera: Mastotermitidae)	NT QLD WA	*Pinus elliottii P. caribaea*				X	X	1
Merimnetes oblongus Blackburn (Coleoptera: Curculionidae)	VIC	*Pinus radiata*		X				1
Merophyas divulsana (Walker) (Lepidoptera: Tortricidae)	NSW SA	*Pinus radiata*	X	X				1
Microcerotermes boreus Hill (Isoptera: Termitidae)	NT WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Microcerotermes distinctus Silvestri (Isoptera: Termitidae)	NSW NT SA VIC WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Microcerotermes implicatus Hill (Isoptera: Termitidae)	NSW VIC	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Microcerotermes nervosus Hill (Isoptera: Termitidae)	NT WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Microcerotermes turneri (Froggatt) (Isoptera: Termitidae)	NSW	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Mordella inusiata Blackburn (Coleoptera: Mordellidae)		*Pinus* spp., *Pseudotsuga menziesii*				X	X	1
Mythimna spp. (Lepidoptera: Noctuidae)	SA	*Pinus radiata*, *Eucalyptus* spp.	X	X				1
Nasutitermes exitiosus (Hill) (Isoptera: Termitidae)	NSW QLD VIC WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Neomerimnetes obstructor Blackburn (Coleoptera: Curculionidae)	SA	*Pinus radiata*	X					1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
***Neotermes insularis* (Walker) (Isoptera: Termitidae)**	NSW VIC ACT SA WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Nysius vinitor Bergroth (Hemiptera: Lygaeidae)	NSW WA	*Eucalyptus globulus, Pinus radiata*	X					1
Ochrogaster contraria Walker (Lepidoptera: Notodontidae)	VIC	*Pinus radiata, Acacia* spp.		X				1
Ochrogaster lunifer Herrich-Schaffer (Lepidoptera: Notodontidae)	NSW QLD SA VIC WA	*Pinus radiata*		X				1
Oiketicus elongatus Saunders (Lepidoptera: Psychidae)	NSW QLD	*Pinus radiata*		X				1
Omyta centrolineata Westwood (Hemiptera: Pentatomidae)	VIC	*Pinus radiata*		X				1
Opodiphthera helena (White) (Lepidoptera: Saturniidae)	NSW QLD TAS SA TAS VIC WA	*Eucalyptus delegatensis, E. diversicolor, E. nitens, E. obliqua, E. regnans, Schinus molle, Betula pendula, Liquidambar sp., Prunus domestica, Quercus robur, Ligustrum vulgare, Pinus radiata*		X				1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Orgyia australis Walker (Lepidoptera: Lymantriidae)	NSW QLD WA	*Pinus radiata, P. taeda*		X				1
Orthorrhinus klugi Boheman (Coleoptera: Curculionidae)	VIC	*Pinus radiata*			X	X		1
Panacela lewinae (Lewin) (Lepidoptera: Eupterotidae)	NSW VIC	*Pinus radiata, P. patula, Angophora floribunda*		X				1
Perperus sp. (Coleoptera: Curculionidae)	ACT	*Pinus radiata*	X	X				1
Persectania ewingii (Westwood) (Lepidoptera: Noctuidae)	SA TAS WA	*Pinus radiata, Eucalyptus* spp.	X	X				1
Phaulacridium vittatum (Sjostedt) (Orthoptera: Acrididae)	NSW QLD SA VIC WA	*Eucalyptus globulus, E. nitens, Pinus radiata*		X				1
Pineus laevis Maskell Homoptera: Adelgidae)	ACT NSW QLD SA VIC WA	*Pinus radiata*		X				1
Pineus pini (Macquardt) (Homoptera: Adelgidae)	ACT VIC QLD	*Pinus radiata*		X				1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/Territory	Hosts	Seedlings in nursery	Foliage/branches	Bark/cambium	Sapwood	Heartwood	Pest Category[b]
***Platypus subgranosus* Schedl (Coleoptera: Platypodidae)**	QLD TAS VIC	*Eucalyptus delegatensis, E. goniocalyx, E. nitens, E. obliqua, E. regnans; E. saligna, Nothofagus cunninghamii, Pinus radiata*				X	X	1
***Porotermes adamsoni* (Froggatt) (Isoptera: Termopsidae)**	ACT NSW QLD SA TAS VIC	*Eucalyptus spp., Pinus radiata, Araucaria cunninghamii, Ceratopetalum apetalum, Nothofagus cunninghamii*					X	1
Procometis sp. (*Lepidoptera: Xyloryctidae*)	SA	*Pinus radiata*		X				1
Pseudaletia sp. (*Lepidoptera: Noctuidae*)	SA	*Pinus radiata, Eucalyptus* spp.	X	X				1
Pseudococcinae (*Hemiptera: Pseudococcidae*)	VIC	*Pinus radiata*		X				
Pycnomerus blackburni Hetschko (*Coleoptera: Colydiidae*)	VIC	*Pinus radiata*					X	1
***Schedorhinotermes intermedius* (Brauer) (Isoptera: Rhinotermitidae)**	NSW NT QLD SA VIC WA	*Eucalyptus spp., Pinus spp.*				X	X	1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/Territory	Hosts	Seedlings in nursery	Foliage/branches	Bark/cambium	Sapwood	Heartwood	Pest Category[b]
Schedorhinotermes reticulatus (Froggatt) (Isoptera: Rhinotermitidae)	NSW QLD VIC WA	*Eucalyptus* spp., *Pinus* spp.				X	X	1
Scotasmus carinirostris Boheman (Coleoptera: Curculionidae)	TAS	*Pinus radiata*		X				1
Sirex noctilio Fabricius (Hymenotera: Siricidae)	NSW SA TAS VIC	*Pinus radiata*				X		2
Teia (=Orgyia) anartoides Walker (Lepidoptera: Lymantriidae)	QLD SA TAS VIC	*Pinus radiata, Eucalyptus* spp.		X				1
Tortricopsis semijunctella Walker (Lepidoptera: Oechophoridae)	NSW QLD TAS SA VIC WA	*Pinus radiata, Eucalyptus* spp., *Cupressus* spp.		X				1
Toxeutes sp. (Coleoptera: Cerambycidae)	WA	*Eucalyptus diversicolor, Pinus radiata*				X		1
Trigonocyttara clandestina Turner (Lepidoptera: Psychidae)	NSW	*Pinus radiata*		X				1

Table 8—Potential insects of concern associated with *Pinus* spp. in Australia, including host range, location on host, and pest category.

Species[a]	State/ Territory	Hosts	Seedlings in nursery	Foliage/ branches	Bark/ cambium	Sapwood	Heartwood	Pest Category[b]
Xyleborus perforans Wollaston (Coleoptera: Scolytidae)	QLD	*Pinus elliottii, Eucalyptus deglupta, E. drepanophylla, E. grandis, E. intermedia, E. seeana, E. tereticornis, Eucalyptus* spp., *Corymbia maculata, C. variegata*				X		1
Zermizinga indocilisaria Walker (Lepidoptera: Geometridae)	VIC	*Pinus radiata*		X				1

[a] Insect species in bold type are treated in Individual Pest Risk Assessments.

[b] See Table 7 for pest category descriptions.

[c] Australian states or New Zealand in parentheses indicates state or country into which introductions of the pest have occurred.

Table 9—Potential pathogens of concern associated with Pinus spp. in Australia, including host range, location on host, and pest category.

Species	State/Territory	Hosts	Seedlings in nursery	Foliage/other	Bark/cambium	Sapwood	Heartwood	Pest Category[b]
Amylostereum areolatum (Chaillet) Boidin (Russulales, Stereaceae)	NSW SA TAS VIC	*Pinus radiata*				X	X	1
Armillaria hinnulea Kile & Watling (Agaricales, Marasmiaceae)	Australia	broad host range			X	X	X	1
Armillaria **luteobubalina Kile & Watling (Agaricales, Marasmiaceae)**	Australia	broad host range			X	X	X	1
Armillaria novae-zealandiae **(G. Stev.) Herink (Agaricales, Marasmiaceae)**	Australia	broad host range			X	X	X	1
Armillaria pallidula Kile & Watling (Agaricales, Marasmiaceae)	Australia	*Eucalyptus* spp., *Pinus* spp.			X	X	X	1
Lophodermium canberrianum W. Stahl ex Minter & Millar (Rhytismatales, Rhytismataceae)	ACT VIC	*P. ponderosa, P. engelmannii*		X				saprophyte
Loranthus pendulus (Santalales, Loranthaceae)	SA	*P. radiata*			X	X		1

Table 9—Potential pathogens of concern associated with Pinus spp. in Australia, including host range, location on host, and pest category.

Species	State/Territory	Hosts	Seedlings in nursery	Foliage/other	Bark/cambium	Sapwood	Heartwood	Pest Category[b]
Muellerina eucalyptoides (DC.) Barlow (Santalaceae, Loranthaceae)	NSW	*Pinus radiata*			X	X		1
Phellinus noxius (Comer) GH Cunn. (Hymenochaetales, Hymenochaetaceae)	QLD	*Pinus* spp.				X	X	1
Sphaeropsis sapinea (Fr.:Fr.) Dyko & Sutton [*Diplodia pinea* (Desmaz.) J. Kickx fil.] (Coelomycetes)	Australia	*Pinus radiata*		X	X	X		4a

[a] Pathogen species in bold type are treated in Individual Pest Risk Assessments.

[b] See Table 7 for pest category descriptions.

INSECT IPRAS

PINE LOOPERS

Assessor—Dennis Haugen

Scientific name of pest—*Chlenias* spp., including *C. auctaria, C. banksiaria, and C. zonaea* (Lepidoptera: Geometridae). However, considerable confusion occurs to the specific identity of *Chlenias* species that feed on pines in Australia (Britton and New 2004).

Scientific names of hosts—Native hosts include a wide range of trees and shrubs, such as *Eucalyptus* spp., *Acacia* spp., *Grevillea* spp., *Hakea* spp., *Nothofagus* spp., and *Cupressus macrocarpa*. Nonnative host: *Pinus radiata*.

Distribution—New South Wales, Victoria, Tasmania, and South Australia

Summary of natural history and basic biology of the pest—*Chlenias* species have one generation per year. Adult moths are present from mid-April until early August. Females do not fly very far from where they emerge; they release a pheromone to attract males for mating. Oviposition occurs on foliage, with a cluster of about 100 eggs laid in two to four rows. Fecundity averages 366 eggs per female, and most eggs are laid within three days after emergence. Females show a preference for high density stands versus isolated trees in open situations, and they generally select the terminal foliage for oviposition. Eggs hatch after 35 to 80 days. There are six larval instars, and larvae are present from July to December. First instar larvae disperse by spinning silk threads and ballooning to other plants. Adult females appear to have little effect on what hosts the larvae settle upon. First instar larvae feed on the foliage surface, while later instars consume entire leaves. Sixth instar larvae move down from the foliage and settle in the litter layer to pupate in silken cocoons. Development from egg to pupa takes approximately 140 days. Pupae are present from December to July (Britton and New 2004; Madden and Bashford 1977a, Elliott et al. 1998).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

   Logs – *Moderate* (RC). Applicable rating criteria from Chapter 1: *b, g*.

   Chips – *Low* (VC) Applicable rating criteria from Chapter 1: none)

   Infrequent localized outbreaks of this moth have occurred throughout its native range on *P. radiata*, so it has the potential of large-scale population increases, but these appear to be rare. An abundance of suitable food, such as high intensity nursery stock or very dense natural regeneration, appears to be a necessary prerequisite for an outbreak in pine (Madden and Bashford 1977b). It is unlikely that this organism would be prevalent on logs or chips, since no life stage is associated with the boles of pine trees. The egg and larval stages only occur on foliage. Pupae occur in the litter layer on the soil surface. Adult females are short-lived (average of six days) and oviposit on foliage. The chipping process would further reduce any

likelihood of any life stage surviving on the commodity. Chips would not be attractive to any life stage or provide a suitable substrate for survival.

2. Entry potential:

Logs – *Low* (VC). Applicable rating criteria from Chapter 1: none.

Chips – *Low* (VC). Applicable rating criteria from Chapter 1: none.

It is unlikely that any life stages of *Chlenias* species would be transported or could survive transportation on logs or chips. Eggs are exposed on the foliage surface, so normal handling of logs would eliminate extraneous foliage or crush the eggs. First instar larvae require young succulent foliage within two days after hatching for survival. Older larvae also require succulent foliage for development.

3. Colonization potential: *High* (RC). Applicable rating criteria from Chapter 1: *b*, *c*, *e*.

Chlenias species are highly polyphagous, thus finding suitable host plants at the importation destination of commodities is likely. It has already shown adaptability to new hosts by attacking *P. radiata* in Australia: a significant expansion of its host range. Its native climatic range is temperate, so it has the potential to establish in many parts of the United States. Also, its high fecun-

dity would increase its colonization potential.

4. Spread potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*, *g*.

The ballooning behavior of the first instar larvae greatly increases the spread potential *Chlenias* species. As with lymantriids, these young larvae could disperse from several hundred meters to many kilometers depending on topography and wind speed. With a broad host range, landing on a suitable host is greatly increased, especially in areas of high diversity of plant species. Coupled with a high fecundity, rapid population expansion would be expected following initial colonization. Potential also exists for inadvertent movement of egg clusters on nursery stock, as nurseries would supply an abundant food resource (Madden and Bashford 1977b).

B. Consequences of introduction

5. Economic damage potential: *Moderate* (VU). Applicable rating criteria from Chapter 1: *a*, *b*.

The occurrence of population outbreaks and impact of resulting defoliations in the United States is a great unknown. The host range in the United States is unknown, but it could span many families of hardwoods and conifers. *Chlenias* species have caused localized defoliation on *P. radiata* in Australia, but the suitability of other North

American pines and conifers is unknown. Even though these loopers have defoliated *P. radiata*, it is a substandard host compared to two of the native host plants (Britton and New 2004). No extensive defoliation has been reported on its native hosts (Madden and Bashford 1977a). Even though this geometrid has a broad host range spanning many plant families, it does not reach outbreak populations on its native hosts.

6. Environmental damage potential: *Moderate* (VU). Applicable rating criteria from Chapter 1: *d*.

    Chlenias species are highly polyphagous, but they rarely reach outbreak populations. Environmental factors appear to keep the populations regulated. From observations of the major outbreak in Tasmania, the pine looper population collapsed due to a reduction in suitable food, increased parasitism and predation, and a virus epidemic (Madden and Bashford 1977b). If any of the *Chlenias* species became established in the United States, the natural controls for native geometrids potentially would regulate this exotic species as well. However, there is potential that a *Chlenias* species could find a suitable host plant with a limited natural distribution and have a significant impact on that plant population.

7. Social and political considerations: *Low* (MC). Applicable rating criteria from Chapter 1: none.

Ornamental plantings would be at a low risk for defoliation based on the oviposition preference of the females (Madden and Bashford 1977a). Regulations and quarantines are unlikely if no major economic damage occurs. An insecticide spray program would not be likely for this exotic geometrid.

C. Pest risk potential

    Logs – *Moderate* (Likelihood of introduction = *Low*; Consequences of introduction = *Moderate*).
    Chips – *Low* (Likelihood of introduction = *Low*; Consequences of introduction = *Moderate*).

Selected Bibliography

Britton, D.R.; New, T.R. 2004. Exotic pine plantations and indigenous Lepidoptera in Australia. Journal of Insect Conservation 8:263-274.

Elliott, H.J.; Ohmart, C.P.; Wylie, F.R. 1998. Insect Pests of Australia Forests: Ecology and Management. Inkata Press. Melbourne, Sydney, Singapore. 214 p.

Madden, J.L.; Bashford, R. 1977a. The life history and behaviour of *Chlenias* sp., a geometrid defoliator of radiata pine in Tasmania. Journal of Australian Entomological Society 16:371-378.

Madden, J.L.; Bashford, R. 1977b. Population biology of *Chlenias* sp., a geometrid defoliator of *Pinus radiata* in Tasmania. Journal of Australian Entomological Society 16:379-388.

Reviewers' Comments

None received.

EXOTIC BARK BEETLES

Assessor—Andris Eglitis

Scientific names of pests—*Hylurgus ligniperda* (Fabricius), *Hylaster ater* Paykull (Coleoptera: Scolytidae)

Scientific names of hosts—*Hylurgus ligniperda*: *Pinus radiata* D. Don, *P. canariensis, P. elliottii, P. halepensis, P. montezumae, P. nigra, P. patula, P. pinaster, P. pinea, P. strobus,* and other *Pinus* spp.; *Hylaster ater*: *Pinus radiata* D. Don, *P. canariensis, P. halepensis, P. muricata, P. pinaster, P. nigra, P. ponderosa, P. sylvestris, Pinus* spp., *Picea* spp., *Abies* spp., *Pseudotsuga* spp., and *Larix* spp.

Distribution—*Hylurgus ligniperda* and *Hylaster ater*: South Australia, New South Wales, and Victoria

Summary of natural history and basic biology of the pests—Boomsma and Adams (1943) stated that *Hylastes ater* was first observed in the Mount Burr area of South Australia in 1936, although it was probably present in Australia well before then. Another early record of these two exotic bark beetles in Australia was made in 1942 when Swan (1942, cited by Brimblecombe 1953) reported *H. ligniperda* in association with *H. ater* damaging a young plantation of *Pinus radiata* after breeding in nearby felled trees. Since that time they have become widely distributed across southern Australia (Elliott et al. 1998).

In Australia, Neumann (1987) reported that *H. ligniperda* and *H. ater* utilize thick-barked logs of large diameter that are in contact with the ground or stumps and dead trees with thick bark at ground level. In down material, several generations can occupy the same log as long as temperature and moisture conditions remain favorable (Boomsma and Adams 1943). Following clearcutting of pine stands, the populations of *H. ater* can reach "epidemic proportions" in the slash, stumps, and other material that remains after a harvest (Adams 1950). Neumann and Marks (1976) list *H. ater* as a nursery pest of seedlings. Sexually immature adults of *H. ater* will feed on seedlings of other genera besides *Pinus*, including *Pseudotsuga*, *Larix*, *Abies* and *Picea* (Milligan 1978; USDA Forest Service 1993). On occasion, the level of seedling mortality caused by *H. ater* has been very impressive, with large numbers of one- and two-year old seedlings being killed in plantation settings and, to a lesser degree, in naturally regenerated stands (Boomsma and Adams 1943). When both bark beetle species occur together in a *P. radiata* plantation, *H. ligniperda* tends to outnumber *H. ater* (Neumann 1987), an observation that was also made in Chilean populations of these bark beetles (USDA Forest Service 1993). Even though *H. ligniperda* and *H. ater* have been less problematic in pine plantations than the exotic *Ips grandicollis*, they have on occasion caused some impressive damage. Neumann (1987) cites authors who reported a case in 1962 in which *H. ater* killed all of the pine seedlings planted over 3.2 hectares in Victoria in the winter of 1962. In South Australia, *H. ligniperda* built up in slash generated after fire salvage harvesting in 1983, and by 1985, beetles had dispersed up to 25 km from the fire area and killed several hundred *P. radiata* trees between four and 14 years old, concentrating their attacks in the root collars and stems near the ground level (Neumann 1987).

Adults of *H. ater* are found throughout the entire year and probably have three generations per year, as they do in New Zealand (Swan 1942). The life cycle of *H. ligniperda* in Australia is likely to be the same, given the climatic similarities with Chile, where three generations per year are reported (Cogollor 1991; USDA Forest Service 1993). Adults of both species appear to favor host material that is in contact with the ground (Eldridge 1983) and their adult and larval galleries often extend into below-ground portions of the host. Both species can develop in material that is somewhere between freshly-cut and down nearly one year (Cogollor 1991; Swan 1942).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

Logs – *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*.

Chips – *Low* (MC). Applicable rating criteria from Chapter 1: *h*.

The transportability of both species has been clearly demonstrated by their introduction into several countries of the southern hemisphere. A broad distribution throughout the host type, a strong attraction to logs and other freshly cut host material, and the ability to produce multiple generations per year virtually assures that adult beetles would be present when host material is harvested and prepared for shipment.

It is difficult to envision that the chip commodity would be likely to harbor life stages of either of these bark beetle species. If infested logs were chipped, the immature life stages either would probably not survive the processing or would perish soon afterwards due to desiccation of the chip or from the extreme heat associated with the interior of a chip pile. Even though uninfested chips might be attractive via their olfactory signals, they would not provide a suitable substrate for colonization. The risk criterion *h* may apply to some degree to those few adult insects that possibly could survive the chipping process if they were beneath the bark when the infested logs were chipped.

2. Entry potential:

Logs – *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*.

Chips – *Moderate* (RU). Applicable rating criteria from Chapter 1: *c*.

All of the life stages of bark beetles are well-protected beneath the bark of host logs, and survival during shipment of at least a few individuals would be expected. The entry potential on a commodity such as pine logs has already been demonstrated for *H. ligniperda*. Schroeder (1990) reported the interception of larvae and adults of *H. ligniperda* in 10 of 14 shipments of <u>debarked</u> pulp logs to Sweden from Chile and France. Haack (2001) lists both *H. ligniperda* and *H. ater* among the top ten scolytid species intercepted in the U.S. between 1985 and 2000.

For chips, the risk criterion *c* is assigned because there is a very small possibility that some adults could survive beneath the bark of chips if the logs were already infested prior to chipping. Nonetheless, the likelihood of successfully transporting these insects in the chip commodity seems very low.

3. Colonization potential: *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*.

Hylurgus ligniperda has become established in several countries, including the U.S. Additional introductions could occur based on the fact that the insect has demonstrated the capability of surviving within a broad climatic band, such as occurs within its distribution in Chile (Ciesla 1988), and because potential pine hosts are widely distributed throughout the U. S. Because both species breed predominantly in pine and are capable of utilizing stumps and fallen branches, their colonization potential is very high.

4. Spread potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*, *f*, *h*.

Almost all of the criteria apply for this risk element, and several of them have already been demonstrated within the U.S. The population of *H. ligniperda* that was discovered recently in New York was believed to have been established 10 years before being detected. At this point, eradication of the population is no longer possible. The abundance of potential host material throughout

the U.S. also figures to aid in the spread of these insects if introduced elsewhere.

B. Consequences of introduction

5. Economic damage potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *a*, *d*.

Neither of these bark beetles appears to be as aggressive or capable of being primary tree-killers, as are many of the indigenous bark beetles associated with *Pinus* spp. in the U.S. *Hylastes ater* has been associated primarily with seedling mortality (Neumann 1987), and *Hylurgus ligniperda* appears to be a tree-killer only after building up in down or damaged material and when live hosts are under some form of stress (Neumann 1987). Furthermore, Neumann and Marks (1990) point out that, even though both scolytids are widely distributed throughout the *P. radiata* plantations of Victoria, damage has been minimal.

In the pest risk assessment of Chilean *P. radiata* (USDA Forest Service 1993), the greatest concern associated with the introduction of these two species was for their potential as vectors of black stain root disease. Two species of *Leptographium* have been isolated from the New Zealand populations of *H. ligniperda* and *H. ater* (MacKenzie 1992). This fungal-insect association is very strong, with the fungus having been isolated from more than 70 percent of the beetles examined (MacKenzie 1992). Typically, only 1 percent to 5 percent of the insect vectors of black

stain root disease in Douglas-fir in the U.S. are carrying the fungus (Witcosky et al. 1986) and probably less than 1 percent in ponderosa pine (Donald J. Goheen, 2005, USDA Forest Service, pers. comm.). As such, there was concern that *H. ligniperda* and *H. ater* could be more efficient vectors of blackstain root disease than the bark beetles endemic to the U.S.

6. Environmental damage potential: *Moderate* (MC). Applicable rating criteria from Chapter 1: *d*.

   Risk criterion *d* could apply if these bark beetles were introduced into the small natural U.S. stands of *P. radiata*.

   As potentially more efficient vectors of black stain root disease, these insects could introduce an additional burden on susceptible native tree species with limited ranges.

7. Social and political considerations: *Moderate* (MC). Applicable rating criteria from Chapter 1: *a*.

   If *H. ater* of *H. ligniperda* became established as successful vectors of black stain root disease, there would certainly be concern from private forest industries and public land management agencies.

C. Pest risk potential

   Logs – *High* (Likelihood of introduction = *High*; Consequences of introduction = *Moderate*).

Chips – *Moderate* (Likelihood of introduction = *Low*; Consequences of introduction = *Moderate*).

Selected Bibliography

Adams, A.J.S. 1950. Control of the pine bark beetle (*Hylastes ater*) at Mt. Burr, South Australia. Australian Forestry 14:111-112.

Bain, J. 1977. *Hylurgus ligniperda* (Fab.). Forest and Timber Insects in New Zealand No. 18. Rotorua: Forest Research Institute, New Zealand Forest Service. 6 p.

Boomsma, C.P.; Adams, A.J.S. 1943. Pine bark beetle (*Hylastes ater*) at Mount Burr, South Australia. Australian Forestry 7:33-37.

Brimblecombe, A.R. 1953. An annotated list of the Scolytidae occurring in Australia. Queensland Journal of Agricultural Science 10:167-205. (Reprinted as Queensland Department of Agriculture and Stock Bulletin No.71. 39 pp.)

Ciesla, W.M. 1988. Pine bark beetles: a new pest management challenge for Chilean forests. Journal of Forestry 86(12):27-31.

Cogollor, G. 1991. Estudio de los antecedcentes biologicos para el control de *Hylurgus ligniperda* e *Hylastes ater* (Coleoptera: Scolytidae) en plantaciones de *Pinus radiata* D. Don., propiedad de Forestal Cholguan. Chile: Bosque de Ingenieria, Ltda., informe final. 69 p.

Eldridge, R.H. 1983. Introduced pine bark beetles in New South Wales. Forestry Commission of New South Wales, Forest Protection Series No. 5: 1-3.

Elliott, H.J.; Ohmart, C.P.; Wylie, F.R. 1998. Insect pests of Australian forests: Ecology and Management. Inkata Press, Melbourne, Sydney, Singapore. 214 p.

Haack, R.A. 2001. Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985-2000. Integrated Pest Management Reviews 6:253-282.

MacKenzie, M. 1992. Potential forest exports and pests from New Zealand. In: Log imports and introduced forest pests into the Pacific Northwest. Symposium Proceedings. Oregon State University, Corvallis; 21-23 April, 1992. 7 p.

Milligan, R.H. 1978. *Hylastes ater* (Paykull), black pine bark beetle. Forest and Timber Insects in New Zealand No. 29. Rotorua: Forest Research Institute, New Zealand Forest Service. 7 p.

Neumann, F.G. 1987. Introduced bark beetles on exotic trees in Australia with special reference to infestations of *Ips grandicollis* in pine plantations. Australian Forestry 50(3):166-178.

Neumann, F.G.; Marks, G.C. 1976. A synopsis of important pests and diseases in Australian forests and nurseries. Australian Forestry 39:83-102.

Neumann, F.G.; Marks, G.C. 1990. Status and management of insect pests and diseases in Victorian softwood plantations. Australian Forestry 53(2):131-144.

Schroeder, L.M. 1990. Occurrence of insects in coniferous roundwood imported to Sweden from France and Chile. EPPO (European and Mediterranean Plant Protection Organization) Bulletin 20:591-596.

Swan, D.C. 1942. The bark beetle *Hylastes ater* Payk. (Coleoptera, Scolytidae) attacking pines in Australia. Journal of Agriculture South Australia 46:86-90.

USDA Forest Service. 1993. Pest risk assessment of the importation of *Pinus radiata*, *Nothofagus dombeyi*, and *Laurelia philippiana* logs from Chile. Miscellaneous Publication 1517. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 248 p.

Witcosky, J.J.; Schowalter, T.D.; Hansen, E.M. 1986. *Hylastes nigrinus* (Coleoptera: Scolytidae), *Pissodes fasciatus*, and *Steremnius carinatus* (Coleoptera: Curculionidae) as vectors of black stain root disease of Douglas-fir. Environmental Entomology 15:1090-1095.

Reviewers' Comments

"An individual PRA was prepared for *H. ligniperda* as a pest by itself. However, this beetle is also a known vector for fungal plant pathogens. When considering the economic and environmental impact of this insect, the potential impact this pest could have as a vector for native or exotic pathogens should be considered. *Leptographium wageneri* is an example of a native root rot and tree killer that would benefit from the introduction of a new vector." (Oregon Department of Agriculture)

"*Hylastes ater* and *Hylurgus ligniperda* are very common and wide-spread in radiata stumps and dying trees in Tasmania and should be added to the State listing." (Bashford)

Response to Comments

One of the key concerns for the introduction of *Hylurgus ligniperda* was for its potential as a more efficient vector of black stain root disease. The association of *H. ligniperda* with *Leptographium* spp. has been documented by Mackenzie (1992) and was referenced in this IPRA under "Economic damage potential" as a basis for that concern.

Tasmania was added to the distributions of *H. ligniperda* and *Hylastes ater*.

AMBROSIA BEETLES

Assessor—Andris Eglitis

Scientific names of pests—*Platypus subgranosus* Schedl (Coleoptera: Platypodidae); *Amasa* (=*Xyleborus*) *truncatus* (Erichson); *Xyleborus perforans* (Wollaston) (Coleoptera: Scolytidae)

Scientific names of hosts—*Platypus subgranosus*: *Pinus radiata* D. Don , *Eucalyptus delegatensis, E. goniocalyx, E. nitens, E. obliqua, E. regnans, E. saligna, Corymbia maculata,* and *Nothofagus cunninghami*; *Amasa truncatus*: *Pinus radiata* D. Don , *Eucalyptus acmenioides, E. camaldulensis, E. piperita, E. propinqua, E. rostrata, E. saligna, Eucalyptus* spp., *Corymbia citriodora, C. maculata,* and *Angophora intermedia; Xyleborus perforans*: *Pinus elliottii* Engelm., *Eucalyptus deglupta, E. drepanophylla, E. grandis, E. intermedia, E. seeana, E. tereticornis, Eucalyptus* spp., *Corymbia maculata,* and *C. variegata*

Distribution—*Platypus subgranosus*: Queensland, Tasmania, Victoria; *Amasa truncatus*: New South Wales, Queensland, Tasmania, South Australia, Victoria, New Zealand; *Xyleborus perforans*: Queensland

Summary of natural history and basic biology of the pests—Ambrosia beetles belong to the families Platypodidae and Scolytidae. The platypodid family of semi-tropical ambrosia beetles is well represented in Australia and New Zealand. Froggatt (1926b) discusses five Australian species of *Platypus* that have a variety of hosts, including *Eucalyptus* in some cases. One of these species (*P. subgranosus*) has also been reported on *Pinus radiata* (Elliott et al. 1998). Some

of these beetles attack freshly cut logs, stumps, and fallen trees having sufficient moisture to support the associated fungus that provides food for the developing larvae. Attacks may also occur in live trees that have been wounded or are in poor condition (Froggatt 1926b), or in some cases, in live trees that are not damaged (Harris et al. 1976). Species attacking live trees can be found in southeastern Australia (Neumann and Harris 1974, Elliott et al. 1998). The platypodid beetles bore deeply into the wood and then form transverse galleries with characteristic oval chambers in double rows that will be occupied by the developing larvae. Attacks occur in the summer and are easily recognized by the boring dust surrounding the main gallery into the wood (Froggatt 1926b). The symbiotic fungi are carried by the beetles in specialized repositories (mycangia) and are introduced into the wood as the beetles construct their tunnels (Neumann and Harris 1974). Only moist wood is infested; as soon as the host material reaches a certain stage of dryness, adults leave the wood and immature stages die in the galleries (Froggatt 1926b). Neumann and Harris (1974) found that the risk of infestation is minimal when moisture content of host material drops below 40 percent, but 20 percent moisture content may be sufficient to sustain a colony that is already present.

The life cycles of platypodid ambrosia beetles are quite variable. Tropical beetles may complete a generation in four to ten weeks while in temperate forests life cycles can vary from 15 months to 5 years (Neumann and Harris 1974). One of the two most important Australian species associated with eucalypts (*Platypus*

subgranosus) requires two to three years to complete a generation (Neumann and Harris 1974). Colonies may contain various developmental stages within the same infested host (Neumann and Harris 1974).

Hogan (1948) studied *P. subgranosus* in the Central Highlands of Victoria and described its life cycle as follows. Adult emergence begins in October and continues until April, with the peak flights occurring in January and March. Flight capability of both sexes is described as "weak and slow" (Hogan 1948). Male beetles find new host material and make the initial entry into the wood by constructing a short gallery about one-half inch long (Hogan 1948). They wait for females to arrive, and mating takes place outside the gallery. The females then continue the remaining gallery excavation and lay their eggs near the far end of the gallery (Hogan 1948). Relatively few eggs are laid by each female: six to ten per gallery at any one time, and oviposition is spread over a long time period (Hogan 1948). There is no additional gallery construction by the female once oviposition has begun, but once larvae are full-grown, they will extend the galleries. The total gallery produced by *P. subgranosus* is relatively short when compared to galleries typical of the platypodid family and are typically 4 to 6 inches (10 to 15 cm) in length (Hogan 1948). Larvae produce fine granular frass, whereas adults produce a "splintery" frass (Hogan 1948). The mature larvae construct pupal chambers and use those to transform into new adults. Only one generation occurs in a given gallery, and new adults emerge from the original entry hole made by the parents

(Hogan 1948). The maximum number of beetles reported emerging from one gallery system is 34 (Hogan 1948). The rate of beetle development is controlled by temperature, and duration of a generation is believed to vary between ten months and five years. An average length of the life cycle in Victoria in the Central Highlands is from two to three years (Hogan 1948). The food source for developing broods is a fungus, identified as *Leptographium lundbergii*, which is introduced by the beetles and grows inside the gallery (Hogan 1948). Yeast is also present in the gallery and may be of equal importance to the fungi as a food source for the beetles (Hogan 1948). *Platypus subgranosus* infests both living trees and fresh logs and causes wood degradation in the process (Neumann and Marks 1976). Neumann and Harris (1974) found long-established colonies of *P. subgranosus* in pure stands of live *Eucalyptus nitens* in eastern Victoria.

Neumann and Marks (1976) reported that *P. subgranosus* has been associated with widespread death of myrtle beech, *Nothofagus cunninghamii*, in Tasmania. The ambrosia beetle has proven to be an inadvertent vector of a pathogenic fungus *Chalara australis* that causes wilt disease (Ian W. Smith, Victoria Department of Natural Resources and Environment, 2001, pers. comm.). *P. subgranosus* infests trees that are dying from wilt disease and, in the process of constructing tunnels, produces copious amounts of frass that contains the wilt fungus. The frass accumulates outside the infested tree and is transported by the wind, along with the fungus, into wounds of otherwise healthy myrtle beeches. These trees then become suf-

ficiently weakened by the wilt fungus to make them susceptible to ambrosia beetle attack, and the cycle continues. (In the absence of the ambrosia beetle, the fungus causing wilt disease spreads by root contact [Ian W. Smith, Victoria Department of Natural Resources and Environment, 2001, pers. comm.]).

In Australia, the scolytid ambrosia beetles have habits similar to the platypodids (Elliott et al. 1998). Some differences do exist, however, including a sex ratio in the scolytids that is strongly skewed toward females, the host-finding sex (Elliott et al. 1998). Females are considerably larger than the males. The females mate after emergence and fly off to establish new broods, which they tend to maturity (Elliott et al. 1998).

The important Australian species of scolytid ambrosia beetles are currently (or at least were) in the genus *Xyleborus*. Wood (1982) describes the genus *Xyleborus* as being exceedingly large and complex. Over 70 species occur in North and Central America, but these represent a small portion of the species occurring worldwide (possibly 1,500 species). Most of the American species are tropical or subtropical, although numerous species also occur in the northernmost states of the U. S. The taxonomy of the genus is also extremely complex, owing in part to the beetles' unique reproductive behavior (arrhenotokous parthenogenesis), which can lead to difficulties in distinguishing species (Wood 1982). The males are relatively rare and are flightless. Females select new host material and establish galleries. An unmated female apparently produces only male offspring. She may later mate with some of these offspring to produce additional females (Wood

1982). Some mating between siblings also occurs in the brood chambers. The developing larvae help to enlarge the galleries that can sometimes be highly complex and branched, or may be much simpler in some beetle species (Wood 1982).

The genus *Xyleborus* includes an array of insects whose hosts range from healthy trees to old logs, but most of the species prefer recently cut, injured, or unthrifty material (Wood 1982). All of the species feed on an associated ambrosial fungus that grows on the walls of their tunnels. The moisture content of host material is critical in order to insure proper growth and survival of this associated fungus; if host material is too dry, the fungus dies; if too wet, the fungal growth overwhelms the galleries and the developing insects suffocate. Damage associated with these insects is in the form of wood degradation due to the fungal staining that occurs in association with adult and brood tunneling. Ambrosia beetles in this genus are generally not considered to be tree killers.

Xyleborus perforans is considered one of the most important ambrosia beetle species in eastern Australia (Elliott et al. 1998), attacking dead and dying trees, green logs, and newly sawn lumber. Less commonly, live trees can also be attacked through wounds or diseased patches of bark (Elliott et al. 1998). Froggatt (1925) reported finding life stages of *X. perforans* in logs that had been cut "months earlier" and submerged in a river for some time before shipment to their destination. Elliott et al. (1998) reported that these polyphagous beetles infested fire-killed *Pinus elliottii* in a plantation and caused considerable damage to wood intended for poles. The

beetles do not discriminate with respect to size of their host: branches as well as large logs can be infested (Elliott et al. 1998). The females construct a tunnel with numerous branches but no brood chambers. Eggs are laid in the parent galleries and the larvae move freely within these tunnels, consuming the ambrosia fungus (Elliott et al. 1998). During the summer, the life cycle can be completed in two to three months (Elliott et al. 1998) and sometimes in as little as four weeks (Peters et al. 1996). These insects are widely distributed throughout the world and have produced considerable economic loss (Elliott et al. 1998).

A *Eucalyptus*-inhabiting species in New Zealand since 1930, *Xyleborus truncatus* (now *Amasa truncatus*) is thought to have a life cycle of less than one year and may complete two generations in a year (Zondag 1977). *Amasa truncatus* appears to have considerably more hosts in New Zealand than in its native Australia, where it is only recorded on *Eucalyptus saligna* and *E. rostrata* (Froggatt 1926a). In New Zealand, the ambrosia beetle has been found breeding in *Leptospermum ericoides*, *L. scoparium*, *Knightia excelsa*, *Metrosideros robusta*, *M. excelsa*, *Weinmannia racemosa*, *Albizzia lophanta*, *Acacia verticillata*, *A. decurrens*, and several species of *Eucalyptus*, including *E. botryoides*, *E. globulus*, *E. obliqua*, *E. ovata* and *E. viminalis* (Zondag 1977). Several other hosts including *Pinus radiata* have also been attacked but no broods were produced in them (Zondag 1977). Zondag (1977) reports that the only living trees to be attacked by *A. truncatus* are eucalypts, especially *E. globulus*, in which severe branch dieback can occur. Attacks on live trees

by the ambrosia beetle are followed by rapid wilting of the foliage, leading to the conclusion that an associated fungus other that the ambrosia fungus may be responsible for killing the sapwood (Zondag 1977). Despite this capability of producing branch dieback and infesting numerous hosts, *A. truncatus* is considered of little economic importance in New Zealand (Zondag 1977).

The adult female of *A. truncatus* bores an entry tunnel into the wood to a depth of about 30 mm. There may be one or two short additional tunnels that branch from the main tunnel (Zondag 1977). Eggs are laid in the far end of the tunnel, and small larvae make a small excavation called a "keyhole chamber," where they feed and develop. Eggs are apparently laid over a long period of time given that larvae of all sizes, pupae, and young adults can all be found in the gallery at the same time (Zondag 1977). Most of the larvae develop into females, which emerge in the spring and summer (Zondag 1977).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

    Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *d*, *e*, *f*, *g*, *h*.

    Chips – *Moderate* (VU). Applicable rating criteria from Chapter 1: *e*, *h*.

    Both of the families of ambrosia beetles possess a strong ability to locate and colonize hosts, be they standing trees or freshly cut mate-

rial, and if log moisture remains suitable, they can survive in this material for some time (Neumann and Harris 1974, Wright and Harris 1974). *P. subgranosus* has a flight period that extends over a significant portion of the year. Host material available in log form could readily be colonized by *P. subgranosus*, if not already infested as a standing tree prior to felling. A "High" rating for the log commodity is derived from the fact that *Xyleborus* ambrosia beetles are frequently intercepted in foreign ports, and risk criterion *a* applies. In an analysis of interception records, Haack (2001) reports that *Xyleborus* is the fifth-most commonly intercepted scolytid genus in the U.S. from Australia.

If infested logs/trees were chipped, it is extremely unlikely that any early developmental stages of ambrosia beetles could survive for any length of time. It is possible that a small percentage of mature adults could survive the chipping process, based on their small size. McNee et al. (2002) found a small number of similarly sized insects (*Pityophthorus* spp.) surviving the chipping of branches infected with pitch canker fungus. The relevance of those observations is a matter of speculation, however, because ambrosia beetles are generally intolerant of changes in the moisture content of the wood, and if surviving the chipping process, those near the surface of the pile might be inclined to leave the chips. If they survived chipping but were well within the pile, they would be subjected to extreme

temperatures that could be lethal. Nonetheless, lacking clear evidence to the contrary, it does seem conceivable that a small percentage of mature individuals could survive in chips, making criteria *e* ("organism likely to survive") and *h* ("organism unlikely to be dislodged during handling") applicable. In the case of material not previously infested, the only risk criterion that applies for the chip commodity is the attractiveness due to the host volatiles emanating from the material. However, this criterion is not significant because chips would not be a suitable substrate for colonization.

2. Entry potential:

   Logs – *High* (RC). Applicable rating criteria from Chapter 1: *b*, *c*.
   Chips – *Moderate* (VU). Applicable rating criteria from Chapter 1: *b*.

   Neumann and Harris (1974) pointed out that platypodids can survive in their host material if the moisture content is above 20 percent. Given the previously stated fact that *Xyleborus* ranks high in interceptions for the Scolytidae (Haack 2001), it is clear that they too could survive in a substrate such as a pine log.

   Because of the importance of moisture content for the successful colonization and survival of these insects, it seems extremely unlikely that chips would harbor live insects after they have been stockpiled and transported, as the moisture levels would likely be altered. However, criteria *b* and *c* could technically apply for a small portion of adults

surviving the chip process and being somewhere near the surface of the pile during transport. A rating of "*Moderate*" is assigned for chips, given the possibility that some adults could survive transport in chips.

3. Colonization potential: *Moderate* (MC). Applicable rating criteria from Chapter 1: *b*, *d*.

   A number of pine hosts for both platypodids and scolytids occur in California and in other parts of the U.S. where introductions could occur.

4. Spread potential: *High* (MC). Applicable rating criteria from Chapter 1: *b*, *e*, *f*, *g*, *h*.

   The reproductive potential of these insects is fairly low, and their innate dispersal capability is unknown. Platypodids and scolytids are fairly cryptic insects. Boring dust on the bole of infested trees would be evident, but would probably be noticed only by close examination of an attacked tree. Infested material may inadvertently be transported by humans to a new location and new infestation centers could be established if suitable hosts were present. Criterion *h* is added because of the capabilities demonstrated by *P. subgranosus* for assisting the spread of Chalara wilt disease in two Australian states and by *Amasa truncatus* for causing dieback in *E. globulus* through an associated fungus that it introduces as it infests live hosts.

B. Consequences of introduction

5. Economic damage potential: *High* (MC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*, *f*.

   The damage associated with platypodid and scolytid ambrosia beetles is primarily wood degradation caused by their galleries and the localized staining by the symbiotic fungi. Neumann and Harris (1974) point out that heavy costs have been incurred throughout the world from the enforcement of stringent quarantine regulations for insects such as these. Controls are currently not available for these insects. There is also concern over the association of these insects with fungi that are clearly pathogenic (e.g., *Chalara australis* with *Platypus subgranosus* and a fungus with *Amasa truncatus*) in their natural environment. Similar associations or vector relationships could be expressed or discovered in other members of this group once introduced into a new environment.

6. Environmental damage potential: *Moderate* (MC). Applicable rating criteria from Chapter 1: *d*.

   The hosts of the scolytid ambrosia beetles are primarily from the family Myrtaceae, although one species (*Xyleborus perforans*) has been associated with *Pinus elliottii*. With two exceptions, the hosts of *P. subgranosus* are all eucalypts that are exotic in the U.S. *Platypus subgranosus* has a beech (*Nothofagus cunninghami*) as a host, but this genus occurs only rarely, as an ornamental in some parts of the U.S. However, attacks

of *P. subgranosus* have also occurred on damaged *Pinus radiata* (Elliott et al. 1998), although the details of this association are unknown. Criterion *d* is applied to this element based on the limited range of *P. radiata,* a potential host for *P. subgranosus,* in the U.S..

7. Social and political considerations *Moderate* (MC). Applicable rating criteria from Chapter 1: *a*.

Although these platypodids and scolytids are not usually agents of mortality, their establishment in native forests or in recreational settings could be of importance, especially if infested live hosts are weakened by decay fungi to the point of causing branch breakage, presenting safety hazards.

C. Pest risk potential

Logs – *High* (Likelihood of introduction = *High*; Consequences of introduction = *High*)

Chips – *Moderate* (Likelihood of introduction = *Moderate*; Consequences of introduction = *High*)

An evaluation of the pest risk potential based on chips rather than logs as the commodity entails revisiting the first two elements of the likelihood of introduction:

1. pest with host at origin potential and
2. entry potential.

These elements for the chip commodity can be evaluated in two ways: first, for potential survival of insects that had already infested

their hosts prior to chipping, and secondly, for chip attractiveness as a substrate for colonization. In the first case, it does not seem that immature life stages could survive in chips because moisture content is such a critical factor in development of these insects. Conceivably, a mature life stage could survive in a chip if that chip were on the surface of a pile, but in reality, that stage of the insect would be likely to be dispersing from the host at that time and might not be present for that reason. Elsewhere within the pile, the heat and moisture that is generated should be unfavorable for any life stage of these insects. In the second case, there may be attraction to a chip pile created by the release of host volatiles, but the substrate would be unfavorable for colonization due to moisture content being different from a host tree or log and due to diminished opportunities for egg-laying. For the chip commodity, both of the first two elements (: pest with host at origin potential" and "entry potential") would drop to "Moderate," causing the overall Likelihood of Introduction to drop to "Moderate" and the Pest Risk Potential to also drop to "Moderate." The "Moderate" Pest Risk Potential rating for the chip commodity is derived from the possibility that a very small portion of mature beetles surviving the chipping process could also survive transport to their new environment.

Selected Bibliography

Elliott, H.J.; Ohmart, C.P.; Wylie, F.R. 1998. Insect pests of Australian forests: Ecology and management. Inkata Press, Melbourne, Sydney, Singapore. 214 p.

Froggatt, W.W. 1925. Forest insects. No. (12) 13. The island pinhole borer (*Xyleborus perforans* Wolliston), Australian Forestry Journal 8:232-234.

Froggatt, W.W. 1926a. Forest insects. No. 21. The ridge-tailed borer. *Amasa truncata,* Erichson. Australian Forestry Journal 9:144-146.

Froggatt, W.W. 1926b. Forest insects. No. 25. Shot hole borers (ambrosia beetles) belonging to the genus *Platypus*. Australian Forestry Journal 9:256-260.

Haack, R. A. 2001. Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985-2000. Integrated Pest Management Reviews 6:253-282.

Harris, J.A.; Campbell, K.G.; Wright, G.M. 1976. Ecological studies on the horizontal borer *Austroplatypus incompertus* (Schedl) (Coleoptera: Platypodidae). Journal of the Entomological Society of Australia (N.S.W.) 9:11-21.

Hogan, T.W. 1948. Pin-hole borers of fire-killed mountain ash. The biology of the pin-hole borer – *Platypus subgranosus* S. Journal of Agriculture, Victoria 46:373-380.

McNee, W.R.; Wood, D.L., Storer, A.J.; Gordon, T.R. 2002. Incidence of the pitch canker pathogen and associated insects in intact and chipped Monterey pine branches. The Canadian Entomologist 134:47-58.

Neumann, F.G.; Harris, J.A. 1974. Pinhole borers in green timber. Australian Forestry 37:132-141.

Neumann, F.G.; Marks, G.C. 1976. A synopsis of important pests and diseases in Australian forests and nurseries. Australian Forestry 39:83-102.

Peters, B.C.; King, J.; Wylie, F.R. 1996. Pests of timber in Queensland. Queensland, Australia: Queensland Forest Research Institute, Department of Primary Industries. 175 p.

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Naturalist Memoirs No. 6. Brigham Young University, Provo UT. 1359 p.

Wright, G.G.; Harris, J.A. 1974. Ambrosia beetle in Victoria. Forests Commission Victoria, Forestry Technical Papers 21:47-57.

Zondag, R. 1977. Xyleborus truncatus Erichson (Coleoptera: Scolytidae). Forest and timber insects in New Zealand. New Zealand Forest Service, Forest Research Institute, Rotorua. No. 21. 4 p.

Reviewers' Comments

"Recent work we have done in the southeastern USA with the introduced *Xyleborus glabratus* has shown that the symbiotic fungal associate of this beetle can cause a serious wilt disease on Lauraceae. No redbay or sassafras are surviving where the ambrosia beetle has become established, and the fungus/beetle appear capable of wiping out these species and other Lauraceae as they spread through the Americas. Because we know so little about the symbionts of ambrosia beetles, I think

that the risk of environmental damage due to introductions of ambrosia beetles should be considered high." (Harrington)

"The record of *Amasa truncatus* from radiata in Tasmania is very doubtful. We have had thousands of Sirex logs go through the insectary over the past 35 years and never had any emerge. Emerged from *Eucalyptus globulus* in Tasmania." (Bashford)

"Finally, in the ambrosia beetle IPRA, we don't understand why the costs to industry because of the lack of control measures has not been considered in assessing the potential economic risk of introducing this pest." (Oregon Department of Agriculture)

"The Ambrosia beetle group is probably the most diverse and complex of all the groups presented. Several dozens of Scolytid and platypodid species have been identified associated with *Pinus* logs in Australia (e.g., Dr Judy King, Queensland Dept. Primary Industries, & Fisheries, pers. comm.) and this is not reflected in Table 8." (Stone)

Response to Comments

The comment about the damage in the southeastern U.S. caused by *Xyleborus glabratus* and its associated fungal symbiont is an important reminder that pest complexes can become more severe in new environments. However, in the case of the IPRA for ambrosia beetles, the Pest Risk Potential is already rated as "High" and would not be increased by raising the Environmental damage potential from "Moderate" to "High."

The insect table does not directly state that *Amasa truncatus* occurs on *Pinus radiata* in Tasmania; rather, it lists Tasmania among the states where the insect occurs and lists *P. radiata* among the many hosts that the insect

utilizes. Our convention in these pest risk assessments has been to assume that if a known host and a known distribution coincide then that pest/host association could occur in that location and mitigation measures would be based on that possibility, even if the association had not been established in that particular location.

In the ambrosia beetle IPRA, the cost of control is considered as a criterion within the risk element of "Economic damage potential" which received a "High" rating.

The insect table was updated to include species that were not listed in the draft document.

PINE BARK WEEVILS

Assessor—Andris Eglitis

Scientific names of pests—*Aesiotes leucurus* Pascoe; *A. notabilis* Pascoe (Coleoptera: Curculionidae)

Scientific names of hosts—*Aesiotes leucurus*: *Pinus radiata, P. halepensis,* and *Callitris* spp.; *A. notabilis*: *Pinus caribaea, P. elliottii, P. montezumae, P. patula, P. radiata, P. taeda, Araucaria cunninghamii, A. cunninghamii* var. *glauca, A. bidwillii, Agathis palmerstonii,* and *A. robusta*

Distribution—*Aesiotes leucurus* and *A. notabilis:* Queensland, New South Wales.

Summary of natural history and basic biology of the pests—The two Australian species of *Aesiotes* are commonly referred to as "pine bark weevils" based on feeding habits that are very similar to those of scolytid bark beetles. *Aesiotes notabilis* appears to be more well-known than *A. leucurus* (Taylor and Hadlington 1948) and has a host range that includes several species of *Pinus* exotic to Australia. The principal host for *A. notabilis* is *Araucaria cunninghamii,* but it has also been recorded on *Pinus caribaea, P. elliottii, P. montezumae* and *P. taeda* (Elliott et al. 1998). The less well-known *A. leucurus*, with a narrower host range, is still of potential significance because one of its hosts is *P. radiata*. Both species are sometimes economically important (Taylor and Hadlington 1948). *Aesiotes notabilis* is most commonly associated with wounds on the host tree (Wylie 1982); as such, there is great potential for damage to occur on hosts that are being pruned in a plantation setting. Down material such as logging debris and thin-

ning slash can also serve as suitable hosts (Brimblecombe 1945; Elliott et al. 1998). In fact, Brimblecombe (1945) reported that *Aesiotes* weevils develop almost as well in some of the exotic *Pinus* slash as they do in their native hosts (*Araucaria* and *Agathis*). Slash of hoop pine (*A. cunninghamii*) was found to remain attractive to *A. notabilis* for about three weeks after felling (Brimblecombe 1945). In addition to being well-known on *P. radiata*, *A. leucurus* is common on ornamental *Cupressus* in the Sydney area (Taylor and Hadlington 1948). Seedlings in nursery settings are sometimes attacked by *A. notabilis*, with larvae tunneling in the main roots (Wylie and Yule 1978). Despite the fairly broad range of hosts for these *Aesiotes* weevils, the genus appears to be obligate to conifers (Brimblecombe 1945).

The life cycle and habits of *A. notabilis* are described by Brimblecombe (1945) and Taylor and Hadlington (1948). Most attacks occur in the summer and fall. Beginning in October, female weevils lay eggs in open wounds in the bark. Oviposition appears to be greatest in the months with high moisture; accordingly, egg-laying increases from November-December through March and then declines rapidly in the dry month of April (Brimblecombe 1945). There is never a complete cessation of egg-laying as adult weevils are present in plantations throughout the year (Brimblecombe 1945). The larvae hatch from the eggs in one to three weeks. Larvae that hatch during the first three days following pruning are the most likely to become established in the host (Brimblecombe 1945). Young larvae feed within the inner bark for approximately

60 days and are capable of eventually girdling and killing their hosts. Once fully grown, the larvae construct a small chip cocoon in the sapwood where pupation takes place. Adults emerge by drilling a hole out through the bark (Taylor and Hadlington 1948). A complete life cycle requires about three months during the summer and five to seven months during the winter, which means that two to three generations can be completed in a year (Brimblecombe 1945). Adult weevils have well-developed wings and can disperse over considerable distances (Elliott et al. 1998). Brimblecombe (1945) pointed out that adults of *A. notabilis* may live for 18 months or more, and during that time, females could lay as many as 700 eggs (a high number for weevils). Attacks are easily recognized by frass ejected from the wound in conjunction with a dark brown seepage down the trunk (Brimblecombe 1945; Taylor and Hadlington 1948).

A. leucurus probably has a very similar biology, but the details are less well-known (Taylor and Hadlington 1948). In the case of *Cupressus*, wounding of the host may not be a necessary precursor for infestation by *A. leucurus* (Taylor and Hadlington 1948). Trees that are infested have usually experienced some form of stress, such as drought or other unfavorable growing conditions (Taylor and Hadlington 1948). These weevils also readily infest felled timber (Froggatt 1923, Elliott et al. 1998). In fact, Froggatt (1923) speculated that a population buildup in down logs may have been the precursor to the mortality of 40 unhealthy young *P. halepensis* trees along a street in Sydney. Tree stress was blamed as additional predisposing factor.

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

   Logs – *High* (MC). Applicable rating criteria from Chapter 1: *b*, *d*, *e*, *f*, *h*.

   Chips – *Low* (MC). Applicable rating criteria from Chapter 1: none.

Bark weevils possess many of the same attributes of scolytid bark beetles and as such, are considered very likely to be associated with a commodity such as freshly cut logs. Given their flight capability (Elliott et al. 1998) and the longevity of the adult stage (Brimblecombe 1945), they would have the ability to infest new host material throughout a significant portion of the year. The *Aesiotes* species do not have particularly broad host ranges, and they are not found beyond the states of Queensland and New South Wales which limits their importance to plantations near the northeastern rain forests of Australia. Being protected beneath the bark, the developmental stages of the weevils would not likely be dislodged during the processing and handling of logs.

If logs or trees were previously infested and were then chipped, it is extremely unlikely that any early developmental stages of the weevils could survive for any length of time after the chipping was complete. In the case of material not previously

infested, the only risk criterion that applies for the chip commodity is the attractiveness due to the host volatiles emanating from the material. However, this criterion is not significant because chips would not be a suitable substrate for colonization.

2. Entry potential:

   Logs – *High* (MC). Applicable rating criteria from Chapter 1: *b*, *c*, *d*.

   Chips – *Low* (MC). Applicable rating criteria from Chapter 1: none.

   Subcortical insects seem to be very well-adapted for surviving within their host material, even when this material is processed and transported over great distances. One of the more impressive documentations of this fact was by Schroeder (1990), who reported on the interception of numerous species of Chilean bark weevils, bark beetles, and wood borers in pulp logs shipped to Sweden. It is important to note that these pulp logs were considered "well-debarked"; yet enough bark remained to permit the successful transport of some life stages of several subcortical insect species. As such, the transportability of *Aesiotes* weevils is considered high for the log commodity. Risk criterion *d* (degree of difficulty in recognizing infested material) is somewhat debatable because of the brown seepage and frass associated with live trees under attack.

Given the substantial size of *Aesiotes* weevils (Brimblecombe 1945) it seems unlikely that the insects could survive either the chipping process or the host desiccation that would follow chipping of infested logs. Accordingly, the entry potential for chips would be rated as "Low."

3. Colonization potential: *High* (MC). Applicable rating criteria from Chapter 1: *b*, *d*, *e*.

   The natural distribution of *Aesiotes* spp. includes the rain forest areas of Queensland and New South Wales with rainfall exceeding 50 inches per year (Brimblecombe 1945). The *Aesiotes* weevils could potentially find suitable climate and hosts in the southeastern U.S. given that they have been associated with some of the southern pine species such as *P. elliottii* and *P. taeda* (Taylor and Hadlington 1948).

4. Spread potential: *Moderate* (MC). Applicable rating criteria from Chapter 1: *c*, *d*, *e*, *f*.

   The spread potential is rated as "Moderate" based on the similarity of these weevils' ecological niches to those of bark beetles, which have demonstrated time and again that they have the capabilities for redistribution, host finding, and establishment in new environments before eventually being discovered. In addition, most of the eradication efforts that have been undertaken against recent invasive insects in the U.S. have been unsuccessful.

B. Consequences of introduction

    5. Economic damage potential: *Moderate* (MC). Applicable rating criteria from Chapter 1: *a*, *b*, *d*.

    The southern pines are economically very important in the U.S. and could be hosts at least for *A. notabilis*. It does appear, however, that the *Aesiotes* weevils are secondary insects, and that host trees would be colonized only if they were under stress from drought or other debilitating agents.

    6. Environmental damage potential: *Moderate* (MC). Applicable rating criteria from Chapter 1: *d*.

    Criterion *d* would most likely apply for *A. leucurus,* which has *Pinus radiata*, a species with limited natural range in the U.S. The criterion would not apply for *A. notabilis* if it became established on *P. taeda* in the South.

    7. Social and political considerations: *Low* (MC). Applicable rating criteria from Chapter 1: *a*.

    There would likely be public concern with the introduction of yet another exotic species into the U.S., but criterion *a* is probably the only one that would apply in this case, giving this risk element a rating of "Low."

C. Pest risk potential

    Logs – *Moderate* (Likelihood of introduction = *Moderate*; Consequences of introduction = *Moderate*).

    Chips – *Low* (MC) (Likelihood of introduction = *Low*; Consequences of introduction = *Moderate*).

Selected Bibliography

Brimblecombe, A.R. 1945. The biology, economic importance and control of the pine bark weevil *Aesiotes notabilis* Pasc. Queensland Journal of Agricultural Science 2:1-88. (Reprinted as Queensland Forest Service Bulletin No. 14. 88 p.)

Elliott, H.J.; Ohmart, C.P.; Wylie, F.R. 1998. Insect pests of Australian forests: Ecology and management. Inkata Press, Melbourne, Sydney, Singapore. 214 p.

Froggatt, W.W. 1923. Forest Insects of Australia. (Government Printer: Sydney). 171 p.

Hadlington, P. 1951. Bark beetles. Forestry Commission of New South Wales, Division of Wood Technology, Technical Notes 5:26-30.

Schroeder, L.M. 1990. Occurrence of insects in coniferous roundwood imported to Sweden from France and Chile. EPPO (European and Mediterranean Plant Protection Organization) Bulletin 20:591-596.

Taylor, K.L.; Hadlington, P. 1948. Forest insects in New South Wales: The mottled cup-moth (*Doratifera vulnerans*). New South Wales Forestry Record 1:42-47.

Wylie, F.R. 1982. Insect problems of *Araucaria* plantations in Papua New Guinea and Australia. Australian Forestry 45:125-131.

Wylie, F.R.; Yule, R.A. 1978. Pine bark weevil. Queensland Department of Forestry, Advisory Leaflet No. 12. 3 p.

Reviewers' Comments

"In addition, the ability of bark weevils to attack non-native hosts suggests that more pines may be at risk than just those in the southeastern U.S. This could impact this pest's risk rating." (Oregon Department of Agriculture)

Response to Comments

The demonstrated ability to utilize new hosts is considered under the element for "Colonization potential," which was already rated as "High" for the *Aesiotes* weevils.

Bark Anobiid of Pine

Assessor—Michael Haverty

Scientific name of pest—*Ernobius mollis* L. (Coleoptera: Anobiidae)

Scientific names of hosts—*Pinus radiata, P. nigra, P.canariensis, P. pinaster, P. sylvestris, P. taeda,* and *Pseudotsuga menziesii*

Distribution—Queensland (Brimblecombe 1957, Peters et al. 1996), New South Wales (Casimir 1958), as well as Western Australia, South Australia, Tasmania, Victoria, A.C.T. (Anonymous 2005). Native to Europe; introduced into Chile, New Zealand (Brockerhoff and Bain 2000), southeastern Canada, and eastern and southern United States; also now established in California (Seybold 2001, Seybold and Tupy 1993).

Summary of natural history and biology of the pest—Anobiidae are often referred to as powderpost beetles because their larvae reduce wood to a mass of powdery or pelleted frass (Ebeling 1975). However, this species acts more like a classic bark beetle. *Ernobius mollis* is associated with fire-scarred trees and logging slash that has aged for at least one year (Billings and Holsten 1969, Billings et al. 1972). This species undergoes a one-year life cycle. Adults appear during the spring and early summer (December through March), and new eggs are laid at the end of summer (Peters et al. 1996). The females deposit eggs under bark scales, and larvae develop in the subcortical layer of the host or in the wood if the bark is thin (Baker 1972). The presence of bark is essential for development (Peters et al. 1996). In Australia, this bark beetle is considered economically

unimportant (Neumann 1979, Peters et al. 1996). In the southern United States and Canada, this beetle occurs in bark beetle-killed trees (Baker 1972) or as a minor wood products pest in pine or spruce flooring (Craighead 1949). Attack of logs or fresh-cut lumber can be prevented by removing all bark. This beetle is not expected to be a mortality agent. However, because of its association with moribund trees, it may play a role in the dispersal of pathogenic fungi (Seybold 2001).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest(s) with host-commodity at origin potential:

   Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *e*, *f*, *g*, *h*.

   Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

   The distribution of *E. mollis* reflects that of a successful, introduced insect. It is found in every state of Australia, but has not yet been verified in the Northern Territory. However, if well-aged logs are exported with bark intact, there is a moderate possibility that infested material could be included. In Sweden, where 14 shipments of debarked *Pinus radiata* pulpwood logs from Chile were inspected at the port of entry, seven contained either live larvae or adults of *E. mollis* (Schroeder 1990). It is easy to imagine similar infestations reaching the United States from

Australia. The frequency of occurrence of this secondary bark beetle with *P. radiata* sawlogs would be less common than with well-aged pulpwood, particularly if the logs are shipped while fresh.

2. Entry potential:

Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*.
Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

Larvae and adults are protected beneath the bark during their entire development cycle and thus could be effectively transported from the Southern Hemisphere. Their frequent interception in Sweden in shipments from Chile (Schroeder 1990) and the number of countries in which it has become established (Hildebrand 2001) are testimonials to the high likelihood of entry.

3. Colonization potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*.

These beetles breed in slash and logs, which could be found around the port of entry. If infested logs are transported to areas containing the slash of host trees, there is the potential for colonization of *E. mollis*. The host range of this beetle includes tree species that grow in northern California and the Pacific Northwest (Gardiner 1953, Hildebrand 2001). The beetle has already become established in the eastern and southern United States (Baker1972) and more recently in

California (Seybold 2001, Seybold and Tupy 1993).

4. Spread potential: *High* (RC). Applicable rating criteria from Chapter 1: *b*, *c*, *d*, *e*, *g*, *h*.

The spread potential for *E. mollis* in the United States would depend on the array of hosts that are suitable for the beetle and competition from secondary bark beetles indigenous to the United States. The known host range takes in many conifer genera (Gardiner 1953, Milligan 1977), most of which are found in the United States, either in natural forests or trees planted as ornamentals.

B. Consequences of introduction

5. Economic damage potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *a*, *b*.

Craighead (1949) refers to *E. mollis* damage to pine and spruce flooring and other woodwork in the eastern United States. If this insect were to become established in additional areas of the United States, damage would most likely be restricted to logging slash, down material, and some dry wood products. The insect would not be expected to kill trees. It is already established in the southern and eastern United States, as well as in California, so additional damage would be negligible in these areas. However, there is a suspicion that *E. mollis* could be implicated in the transfer of pathogenic fungi (Seybold 2001).

6. Environmental damage potential: *Moderate* (MC). Applicable rating criterion from Chapter 1: *d*.

   Due to the secondary nature of this insect, environmental damage is expected to be minimal. However, if it were to facilitate the transmission of pathogenic fungi in Monterey pine, with its limited natural distribution in California, the risk of environmental damage would increase.

7. Social and political considerations: *Low* (RC). Applicable rating criteria from Chapter 1: none.

   There is a remote possibility that *E. mollis* could become associated with ornamental pines or other trees in urban settings (Seybold 2001, Seybold and Tupy 1993), but it would probably have a minimal effect. Perceived damage would be greater if this insect becomes established in wood products in use.

C. Pest risk potential

   Logs – *High* (Likelihood of introduction = *High*, Consequences of introduction = *Moderate*).

   Chips – *Low* (Likelihood of introduction = *Low*, Consequences of introduction = *Moderate*).

Selected Bibliography

Anonymous. 2005. Australian Insect Common Names. CSIRO. *http://www.ento. csiro.au/aicn/index.htm.*

Baker, W.L. 1972. Eastern forest insects. Miscellaneous Publication 1175. Washington, D.C; U.S. Department of Agriculture, Forest Service. 642. p.

Billings, R.F.; Holsten, E.H. 1969. Progreso realizado en la investigación de insectos forestales de pino insigne (Dic. 1967 hasta Agosto 1969). Santiago: División Forestal, Servicio Agrícola y Ganadero, Universidad de Chile, Cuerpo de Paz. 49 p. (Mimeographed report.)

Billings, R.F.; Holsten, E.H.; Eglitis, A. 1972. Insects associated with *Pinus radiata* D. Don in Chile. Turrialba (Costa Rica) 22(1):105-108.

Brimblecombe, A.R. 1957. The pine bark anobiid. Queensland Agricultural Journal 83:637-639.

Brockerhoff, E.G.; Bain, J. 2000. Biosecurity implications of exotic beetles attacking trees and shrubs in New Zealand. New Zealand Plant Protection 53:321-327.

Casimir, J.M. 1958. *Ernobius mollis* Linn., an introduced bark beetle. Forestry Commission of New South Wales, Division of Wood Technology, Technical Notes 11:24-27.

Craighead, F.C. 1949. Insect enemies of eastern forests. Miscellaneous Publication 657. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 679 p.

Ebeling, W. 1975. Urban entomology. University of California, Division of Agricultural Sciences. 695 p.

Gardiner, P. 1953. The biology and morphology of Ernobius mollis L. (Coleoptera: Anobiidae). Trans. Roy. Entom. Soc. Lond. 104:1-24.

Hildebrand, D.M. 2001. Ernobius mollis. Pest Reports – EXFOR Database. *http://spfnic.fs.fed.us/exfor/data/pestreports.cfm.*

Milligan, R.H. 1977. *Ernobius mollis* Linnaeus (Coleoptera: Anobiidae), pine bark anobiid. Forest and Timber Insects in New Zealand 17. Rotorua: Forest Research Institute, New Zealand Forest Service. 7 p.

Neumann, F.G. 1979. Beetle communities in eucalypt and pine forests in northeastern Victoria. Australian Forestry Research 9:277-293.

Peters, B.C.; King, J.; Wylie, F.R. 1996. Pests of timber in Queensland. Queensland Forest Research Institute, Department of Primary Industries, Queensland. 175 p.

Schroeder, L.M. 1990. Occurrence of insects in coniferous roundwood imported to Sweden from France and Chile. EPPO (European and Mediterranean Plant Protection Organization) Bulletin 20: 591-596.

Seybold, S.J. 2001. *Ernobius mollis* (L.) (Coleoptera: Scolytidae): an exotic beetle colonizes Monterey pine, *Pinus radiata* D. Don, in northern California. Pan-Pacific Entomologist 77:51-53.

Seybold, S.J.; Tupy, J.L. 1993. *Ernobius mollis* (L.) (Coleoptera: Scolytidae) established in California. Pan-Pacific Entomologist 69:36-40.

Reviewers' Comments

None received.

Sirex Woodwasp

Assessor—Dennis Haugen

Scientific name of pest—*Sirex noctilio* F. (Hymenoptera: Siricidae)

Scientific names of hosts—*Pinus* spp., especially *P. radiata*

Distribution—New South Wales, Victoria, Tasmania, South Australia

Summary of natural history and basic biology of the pest—*Sirex noctilio* is endemic to Europe, Asia and northern Africa, and reaches its greatest density in the Mediterranean zone (Spradbery and Kirk 1978, Medvedev 1993). *Sirex noctilio* is generally considered to be a secondary pest of trees in its native range (Spradbery and Kirk 1978). It is established in New Zealand (1900), Tasmania (1952), the Australian mainland (1961), and more recently, in Uruguay (1980), Argentina (1985), Brazil (1988), and South Africa (1994). In Australia and South America it causes significant tree mortality and is considered a major pest (Taylor 1981, Oliveira et al. 1998). In June 2005, an established population of *S. noctilio* was confirmed near Oswego, New York.

Tree species attacked by *S. noctilio* in its native range are almost exclusively pines (e.g., *Pinus pinaster*, *P. sylvestris*, *P. nigra*, and *P. pinea*), but it also has been recorded in fir and spruce (Spradbery and Kirk 1978). *Sirex noctilio* has been reported in larch and Douglas-fir (Krombein et al. 1979), but these reports are very rare occurrences or mis-identifications. In New Zealand and Australia, the main host is *Pinus radiata*, a tree native to California. In Argentina, Brazil, and Uruguay, the main host is *Pinus taeda*, a tree native to the southeastern United States. Other known host species include *Pinus elliottii, P. echinata, P. palustris, P. patula, P. ponderosa, P. contorta, P. banksiana, P. caribaea, P. kesiya*, and *P. strobus* var. *chiapensis* (Duraflora 1993, Maderni 1998). Under stress condition, any *Pinus* spp. appears to be susceptible to attack by *S. noctilio*.

Much of the research on *S. noctilio* has been conducted in Australia and New Zealand, so the following information relates to the situation in these countries. *Sirex noctilio* normally completes one generation per year in southeastern Australia, but in the cooler climates of Tasmania and New Zealand, a portion of a population may take two years (Taylor 1981). In Australia, adults emerge from early summer to early winter, with peak emergence in late summer or early autumn. Males usually predominate, with sex ratios of 4:1 to 7:1 (Morgan and Stewart 1966, Neumann and Minko 1981). Females are attracted to physiologically stressed trees after an initial flight, which is usually less than two miles' distance, but with the potential of up to 125 miles (Bedding and Iede 2005). Female wasps drill their ovipositors into the outer sapwood to inject a symbiotic fungus (*Amylostereum areolatum*) and toxic mucus (Talbot 1964, 1977). If the tree is suitable, eggs are laid into the sapwood (up to three separate eggs at a drill site). The fungus and mucus act together to kill the tree and create a suitable environment for the developing larvae (Coutts 1969a, 1969b, 1969c). Crown wilt does not occur until a cross section of wood in at least one part of the stem has been invaded and killed by the fungus. Fecundity ranges from 21 to 458

eggs, depending upon size of the female (Neumann and Minko 1981). The eggs usually hatch within 10 to 15 days, but in cooler climates, some may overwinter. Unfertilized eggs develop into males, while fertilized eggs produce females. All larval instars feed on the fungus as they tunnel through the wood. Larval galleries may penetrate to the center of a tree. The number of instars varies from 6 to 12, and the larval stage generally lasts from 10 to 11 months. Mature larvae pupate close to the bark surface, and adults emerge about three weeks later (Madden 1988, Taylor 1981).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

   Logs – *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *e*, *f*, *g*, *h*.
   Chips – *Low* (VC). Applicable rating criteria from Chapter 1: *c*.

   Sirex noctilio is likely to be found in pine logs that are produced in the infested Australian states. The probability is even greater if outbreaks are occurring. Low-quality trees harvested from a first thinning of pine plantations have a higher risk of being infested with *S. noctilio* than the final crop of trees for high-quality saw timber and veneer. The larval stage of *S. noctilio* is found at all depths in the wood and would be expected in untreated milled lumber from infested trees. Through the transport of infested logs and

lumber, *S. noctilio* already has been transported to many parts of the world. The chipping process would prevent survival by killing large larvae and pupae or by destroying the substrate required for eggs or small larvae to complete development.

2. Entry potential:

   Logs – *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*.
   Chips – *Low* (VC). Applicable rating criteria from Chapter 1: none.

   Survival of *S. noctilio* life stages in logs can be very high. Survival greatly depends on a suitable moisture content for fungal growth—e.g., above 20 percent oven-dried weight (Talbot 1977)—but even eggs and young larvae are likely to complete development in logs. Because its life cycle is generally a year or longer, *S. noctilio* could easily survive the transit period within the logs. All life stages that occur in the log are likely to escape detection at ports-of-entry, while only emerging adults are likely to be noticed. Chips would not be a suitable environment for survival.

3. Colonization potential: *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*.

   Sirex noctilio has established in many countries outside of its native range. It can successfully attack many species of *Pinus*, including pine species not from its native range. A high probability of colonization is expected for pines near

ports-of-entry and/or destinations of infested pine logs. Abundance of pine plantations in the susceptible age class within close proximity to the entry location would significantly increase the colonization potential. Based on its native range in Europe and Asia, *S. noctilio* could establish in any climatic zone of the continental United States with pine species (Carnegie et al. 2005).

4. Spread potential: *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*, *f*, *g*.

If *S. noctilio* became established, it is likely to spread throughout the United States. Natural dispersal of *S. noctilio* has been estimated at 20 to 30 miles per year in Australia (Haugen et al. 1990). Adult females are capable of long dispersal flights and have high fecundity. Also, populations could be transported and established throughout the United States by movement of infested logs and lumber. Newly established populations are also difficult to detect because suppressed and low vigor trees are attacked first. So before a population is detected, it will have spread over a large area (thousands of square miles), making eradication infeasible.

B. Consequences of introduction

5. Economic damage potential: *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*.

Sirex noctilio has the potential to cause significant mortality in overstocked pine plantations and stressed forest stands. In Australia,

S. noctilio caused up to 80 percent tree mortality in *Pinus radiata* plantations. In one year, *S. noctilio* killed 1.75 million trees in 141,000 acres of plantations aged 10 to 30 years (Haugen and Underdown 1990). The potential damage due to *S. noctilio* in Australia was estimated at between US$16 and US$60 million per year (Bedding and Iede 2005).

Loblolly pine plantations in the southeastern United States would potentially have significant economic losses from an introduction of *S. noctilio*. Pine forests of the western United States could be impacted by *S. noctilio* establishment. Even with a conservative estimation of tree mortality, an economic analysis projected losses of $24 million to $130 million (USDA Forest Service 1992). A later analysis projected losses at three introduction points over 30 years with the following results: $48 million to 607 million for Georgia, $7 to $76 million for Minnesota, and $7 million to $77 million for California (USDA 2000).

However, an efficient biological control agent is available that can reduce and maintain *S. noctilio* populations below the economic damage threshold. A parasitic nematode, *Deladenus siricidicola* Bedding, can be mass-produced and inoculated into *S. noctilio* populations as they invade and colonize new territories (Bedding 1972, Bedding and Akhurst 1974, 1978).

6. Environmental damage potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*.

The effect of *Sirex noctilio* on the native pine forests of the United States could be significant. Changes in stand composition could occur with the selective mortality of pines due to an invasion of *S. noctilio.* The potential damage to these stands would be increased during droughts or other climatic events that reduce tree vigor. Also, an increase in *S. noctilio*-associated tree mortality may increase the populations of other destructive pests, such as bark beetles or root rot pathogens. The establishment of *S. noctilio* in the forests of the United States would affect the populations of other insects. *Sirex noctilio* would be in competition with native siricids, and because *S. noctilio* is more aggressive, it may reduce populations of native species. An expanding *S. noctilio* population would result in population increases of the native parasites of siricids (e.g., *Rhyssa* spp., *Megarhyssa nortoni, Schlettererius cinctipes,* and *Ibalia* spp.), which could further decrease the native siricid fauna (Kirk 1974, 1975). A significant reduction in the genetic base of *Pinus radiata* and *P. torreyana* could occur if *S. noctilio* became established in the remaining native stands.

7. Social and political considerations: *High* (RC). Applicable rating criteria from Chapter 1: *b*, *c*.

Sirex noctilio has caused great concern around the world. Australia developed a national research program and a national fund for a biological control program in response to *S. noctilio* establishment on the mainland. Brazil views *S. noctilio* as the number one threat to its pine plantations and is implementing an intensive biological control program (Iede et al. 1998). Establishment in the United States would impact interstate commerce and would likely require domestic quarantines, as well as have implications for international trade.

C. Pest risk potential

Logs – *High* (Likelihood of introduction = *High*; Consequences of introduction = *High*).

Chips – *Low* (Likelihood of introduction = *Low*; Consequences of introduction = *High*).

Selected Bibliography

Bedding, R.A. 1972. Biology *of Deladenus siricidicola* (Neotylenchidae) an entomophagous- mycetophagous nematode parasitic in siricid woodwasps. Nematologica 18:482-493.

Bedding, R.A.; Akhurst, R.J. 1974. Use of the nematode *Deladenus siricidicola* in the biological control of *Sirex noctilio* in Australia. Journal of the Australian Entomological Society 13:129-135.

Bedding, R.A.; Akhurst, R.J. 1978. Geographical distribution and host preferences of *Deladenus* species (Nematoda: Neotylenchidae) parasitic in siricid woodwasps and associated hymenopterous parasitoids. Nematologica 24:286-294.

Bedding, R.A.; Iede, E.T. 2005. Application of *Beddingia siricidicola* for sirex woodwasp control. Pp. 385-399. In: Grewal, P.S.; Ehlers, R.-U.; Shapiro-Ilan, D.I., eds. Nematodes as biological control agents. CABI Publishing.

Carnegie, A.J.; et al.. 2005. Predicting the potential distribution of *Sirex noctilio* (Hymenoptera: Siricidae), a significant exotic pest of *Pinus* plantations. Annals of Forest Science 63:1-9.

Coutts, M. P. 1969a. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata.* I. effects of the symbiotic fungus *Amylostereum* spp. (Thelophoraceae). Australian Journal of Biological Science 22:915-924.

Coutts, M. P. 1969b. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata*. II. effects of *S. noctilio* mucus. Australian Journal of Biological Science 22:1153-1161.

Coutts, M. P. 1969c. The formation of polyphenols in small blocks of *Pinus radiata* sapwood with and without the fungal symbiont of *Sirex*. Australian Forestry Research 4(l):29-34.

Duraflora, E.T. 1993. Susceptibilidade de toras de pinheiros tropicais ao ataque da vespa-da-madeira *Sirex noctilio* (Hymenoptera: Siricidae). Pp. 97-109. In: Conferencia Regional da Vespa da Madeira, *Sirex noctilio*, na America do Sul. EMBRAPA, Colombo, PR, Brasil.

Haugen, D.A.; Underdown, M.G. 1990. *Sirex noctilio* control program in response to the 1987 Green Triangle outbreak. Australian Forestry 53:33-40.

Haugen, D.A.; Bedding, R.A.; Underdown, M.G.; Neumann, F.G. 1990. National strategy for control of *Sirex noctilio* in Australia. Australian Forest Grower 13(2): special liftout section No. 13. 8 p.

Iede, E.T.; Penteado, S.R.C.; Schaitza, E.G., 1998. *Sirex noctilio* problem in Brazil: detection, evaluation, and control. Pp. 45-52. In: Proceeding of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA Forest Service, FHTET 98-13.

Kirk, A.A. 1974. Siricid woodwasps and their associated parasitoids in the southeastern United States (Hymenoptera: Siricidae). Journal of the Georgia Entomological Society 9:139-144.

Kirk, A.A. 1975. Siricid woodwasps and their associated parasitoids in the southwestern United States (Hymenoptera: Siricidae). Pan-Pacific Entomologist. 51: 57-61.

Krombein, K.V.; et al.. 1979. Catalogue of Hymenoptera in America north of Mexico, Vol. 1, (Symphyta and Apocrita). Washington, D.C., Smithsonian Institution Press.

Madden, J.L. 1988. *Sirex* in Australia. Pp. 407-429. In: Berryman, A.A., ed. Dynamics of forest insect populations. New York: Plenum.

Maderni, J.F.P. 1998. *Sirex noctilio* F.: present status in Uruguay. Pp.81-82. In: Proceeding of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA Forest Service, FHTET 98-13.

Medvedev, G.S. 1993. Keys to the Insects of the European Part of the USSR. Vol. 3 Hymenoptera, Part 4 Symphyta. Amerind. Pub. Co., New Delhi.

Morgan, F.D.; Stewart, N.C. 1966. The biology and behaviour of the woodwasp *Sirex noctilio* F. in New Zealand. Transactions of the Royal Society of New Zealand (Zoology) 7:195-204.

Neumann, F.G.; Minko, G. 1981. The *Sirex* woodwasp in Australian radiata pine plantations. Australian Forestry 44:46-63.

Oliveira, E.B.; Penteado, S.R.C.; Iede, E.T. 1998. Forest management for the prevention and control of *Sirex noctilio* in *Pinus radiata*. Pp.67-75. In: Proceeding of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA Forest Service, FHTET 98-13.

Spradbery, J.P.; Kirk, A.A. 1978. Aspects of the ecology of siricid woodwasps (Hymenoptera: Siricidae) in Europe, North Africa and Turkey with special reference to the biological control of *Sirex noctilio* F. in Australia. Bulletin of Entomological Research 68:341-359.

Talbot, P.H.B. 1964. Taxonomy of the fungus associated with *Sirex noctilio*. Australian Journal of Botany 12:46-52.

Talbot, P.H.B. 1977. The *Sirex-Amylostereum-Pinus* association. Annual Review of Phytopathology 15:41-54.

Taylor, K.L. 1981. The sirex woodwasp: ecology and control of an introduced forest insect. Pp. 231-248. In: Kitching, R.L.; Jones, R.E., eds. The ecology of pests - some Australian case histories. Melbourne: CSIRO.

USDA. 2000. Pest risk assessment for importation of solid wood packing materials into the United States. Draft August 2000, unpublished report. 275 p. *www. aphis.usda.gov/ppq/pra/swpm/*

USDA Forest Service. 1992. Pest risk assessment of the importation of *Pinus radiata* and Douglas-fir Logs from New Zealand. USDA Forest Service Miscellaneous Publication No. 1508. Washington D.C.: USDA Department of Agriculture, Forest Service.

Reviewers' Comments

None received.

Giant/Dampwood Termites

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Scientific name of pest—Giant termite: *Mastotermes darwiniensis* Froggatt (Isoptera: Mastotermitidae; dampwood termite: *Porotermes adamsoni* (Froggatt) (Isoptera: Termopsidae)

Scientific names of hosts—*M. darwiniensis* will attack or infest just about any hardwood or softwood species, including live fruit trees. Colonies of *P. adamsoni* infest live trees in eucalypt forests, particularly in high quality *Eucalyptus delegatensis* and *E. regnans* forests. This species can also cause damage to the heartwood of *Pinus radiata* (Minko 1965), *Araucaria cunninghamii*, *Ceratopetalum apetalum*, and *Nothofagus cunninghamii*.

Distribution—*Mastotermes darwiniensis* is a tropical species that is widely distributed in the Northern Territory, north Queensland, and Western Australia. The southern limit of its distribution is approximately the Tropic of Capricorn, both in coastal and inland localities (Gay and Calaby 1970, French 1986, Elliott et al. 1998). *Porotermes adamsoni* has a wide distribution in southern Australia. It is found in coastal and adjacent highland areas from southern Queensland west to South Australia and south to Tasmania (Gay and Calaby 1970, French 1986, Elliott et al. 1998).

Summary of natural history and biology of the pest—All species of termites are social insects and live in colonies. Some species of the higher termites, such as *Coptotermes* or *Nasutitermes,* are found in discrete nest structures and construct mounds. *Mastotermes* and *Porotermes* live in diffuse nests, usually within one piece of wood. Generally, there are five types of individuals in a colony: immatures or larvae, workers, soldiers, reproductives, and nymphs (Miller 1969). Nymphs will eventually metamorphose into adults with wings (alates) that serve to disperse and establish new colonies a significant distance from the natal colony. Colonies contain a large proportion of wingless workers whose role is the care of the immatures and reproductives, whereas the soldiers defend the colony from predators. These workers are the individuals that damage wood. Flights of the future reproductives (alates) generally occur during summer. In *Mastotermes* and *Porotermes*, workers and nymphs are capable of becoming replacement (or supplementary) reproductives and assuming the reproductive role if their subunit is permanently separated from the main colony. If a colony is somehow broken into one or more subunits, even without reproductives, these subunits are capable of continuing all of the functions of the parent colony. It is primarily this capacity for establishing new colonies (by budding) from subcolonies that makes dampwood termites a threat for introduction into non-endemic sites.

The Mastotermitidae (*Mastotermes darwiniensis*) and the Termopsidae (*Porotermes adamsoni*) are thought to be the most primitive living termites (Thorne and Carpenter 1992). *Mastotermes* is one of the most destructive Australian termites, although its total economic impact on forests and timber is less than several others because of its limited distribution.

It attacks wood in use, as well as growing trees, shrubs, and vegetables (Peters et al. 1996). *Mastotermes* is not a mound builder, and normally it nests in or under the boles of trees or in logs or stumps (Elliott et al. 1998). Under natural conditions, colonies of *M. darwiniensis* attain population levels less than 100,000, but may sometimes have colonies of more than 1,000,000 (Gay and Calaby 1970). Knowledge of the foundation of new colonies is scant. Colonies are normally headed by replacement reproductives; primary queens have only been seen once. Neither the primary nor replacement reproductives are significantly physogastric. The rarity of primary reproductives and the prevalence of relatively small colonies containing replacement queens suggests that new colonies are likely formed by budding from the parent colony (Gay and Calaby 1970).

Porotermes adamsoni lives mainly in hardwood forests, where it forms moderately large colonies in both dead and living trees, as well as in logs. In living trees, colonies begin in scars caused by fire or mechanical damage near the base of tree trunks, but may also originate in branch stub holes up to 30 m above the ground. Infestation rarely occurs until trees have attained a diameter of ca. 0.3 m, and never occurs in undamaged living tissue of the tree. Colonies can also be founded in wood in use, particularly when it is damp through contact with soil and/or poor ventilation. In Tasmania, Victoria, and New South Wales, *P. adamsoni* is considered a significant pest in indigenous forests, especially in older trees (Greaves et al. 1965, Greaves 1959, Elliott and Bashford 1984). *Pinus*

radiata attacked by *Porotermes* seldom show any outward sign of damage 0.6 to 1.2-m long butt log. Trees are attacked below the ground level with the entrance through living bark. Colonies are small, and the extent of their gallery system depends on how much of the root material is decomposed by fungi. Winged adults occur in colonies in the summer (December to early February in Australia). Colonizing flights take place in the early evening; the entire population of winged adults appear to leave at once. Replacement reproductives are commonly produced, especially where gallery systems are very extensive and diffuse.

Several species of dampwood termites are mentioned by Edwards and Mill (1986) as significant pests of wood in buildings. Occasionally they have been exported to other countries, but rarely have they become established. *Mastotermes* has become established in New Guinea and has been found attacking structural timber, posts, and numerous living trees and shrubs (Gay 1969). *Porotermes* has been introduced to New Zealand on at least four occasions in wood other than *Eucalyptus* logs, but has not become established. Similarly, the dampwood termite, *Zootermopsis angusticollis* (Hagen), from the Pacific coastal area of the United States has been introduced to numerous localities throughout the world (Gay 1969), and has now become established on the island of Maui, Hawaii (Woodrow et al. 1999, Haverty et al. 2000).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest(s) with host-commodity at origin potential:

    Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*, *e*, *f*, *g*, *h*.

    Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

    Pinus carribaea and *P. radiata* could supply harborage for *M. darwiniensis* and *P. adamsoni*, respectively (Paton and Creffield 1987, Minko 1965). The likelihood of association of dampwood termites with freshly cut logs is greater in plantations in which silvicultural practices include precommercial thinning and use of prescribed fire. *Mastotermes* has a limited distribution for pines that are harvested for wood chips. *Porotermes* occurs throughout much of the range of *Pinus radiata* harvested for wood chips. However, the damage done by these termites can be detected in logs and should result in redirecting logs to a local chip mill rather than shipping the logs overseas. Colonies or subcolonies of neither *M. darwiniensis* nor *P. adamsoni* would survive the chipping process.

2. Entry potential:

    Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*.

    Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

Mastotermes darwiniensis has been introduced and is established in New Guinea. *Porotermes* has been introduced numerous times into New Zealand, but has not yet become established. Viable colonies of either *M. darwiniensis* or *P. adamsoni* would likely survive the 14-day journey to port cities in the United States, although they should be detectable within the moist cavity in the log by the presence of the packed fecal material or an extensive gallery system. Recently cut logs and the moist fecal material would provide conditions suitable to dampwood termites during transit. The greatest danger exists if items are shipped from plantations in Australia with these species present and remain in storage at the import site, in a suitable habitat such as Hawaii or Puerto Rico, for extended periods of time. Wood chips are not likely to harbor viable groups of termites.

3. Colonization potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*.

    Mastotermes has become established in New Guinea, but *P. adamsoni* has not become established elsewhere. Neither *M. darwiniensis* nor *P. adamsoni* are restricted by hosts. *M. darwiniensis* can infest numerous species of live trees. Even partial colonies can contain many individuals capable of differentiating into a reproductive caste. If a colony contains alates and they were to fly after arriving in the United States, incipient colonies could easily be established. Because these damp-

wood termites can infest numerous tree species and wood in use, the presence of an acceptable host is not the critical factor. Rather, a suitable environment with an adequate supply of wood and appropriate temperature and moisture conditions are the key factors. The initiation of a colony is a slow process, but wood in ground contact, moist wood in structures, and suitable host trees with scars or wounds at ports and storage facilities may provide an infestation site. The adults (alates) fly only about 100 m, but are capable of moving up to 1 km depending on wind conditions and weather. Long-range (> 10 km) establishment of colonies from alates has a very low probability. Colonization potential would depend on the genus; warm, moist conditions would be conducive to *Mastotermes*, and cool, moist conditions would likely favor *Porotermes*.

4. Spread potential: *High* (RC). Applicable rating criteria from Chapter 1: *b*, *c*, *d*, *e*, *f*, *g*.

   Termites spread slowly (15 to 300 m per year), and less than 1 percent of the alates eventually establish a new colony. However, an important factor concerning dampwood termites is that infested wood or plants in containers with soil, moved by humans in commerce, spreads termites at a much faster rate than their natural spread. Also, once established at the receiving seaport or inland destinations, dampwood termites are often not detected because of their cryptic habits; colonies can

be large before the first evidence of their activities is apparent. By this time, multiple colonies can already be established adjacent to the invading colony and additional wood or plants could become infested and distributed within the continental United States or its possessions. Furthermore, dampwood termite infestations could be misdiagnosed or confused with endemic species.

B. Consequences of introduction

5. Economic damage potential: *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *f*.

   Dampwood termites will attack untreated wood and live trees. Neither of these termites discussed here would do well in extremely cold climates, but could be a problem in moist, warm climates along the western, southern, and southeastern coasts of the continental United States and subtropical and tropical locations of the United States and its protectorates and possessions. These termites could pose a significant hazard to the numerous eucalypts and pines planted as ornamentals, for windbreaks, or for fiber. Furthermore, many of these same areas are known for fruit and nut trees. Control methods for termites are available, but can be expensive and could be a risk to environmental quality through increased pesticide use.

6. Environmental damage potential: *Moderate* (MC). Applicable rating criterion from Chapter 1: *d*.

These termites would not likely cause large outbreaks or kill an excessive number of trees. Trees at greatest risk would be fruit trees, street trees, or native trees with a limited distribution, such as Torrey pine (*Pinus torreyana*).

7. Social and political considerations: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *c*.

Damage to wood in structures and to fruit or ornamental trees would cause significant concerns, adding to concerns about other exotic termite species.

C. Pest risk potential

Logs – *High* (Likelihood of introduction = *High*; Consequences of introduction = *High*).

Chips – *Low* (Likelihood of introduction = *Low*; Consequences of introduction = *High*).

Selected Bibliography

Edwards, R.; Mill, A.E. 1986. Termites in buildings: their biology and control. East Grinstead: Rentokil Limited. 261 p.

Elliott, H.J.; Bashford, R. 1984. Incidence and effects of the dampwood termite, *Porotermes adamsoni*, in two Tasmanian east coast eucalypt forests. Australian Forestry 47:11-15.

Elliott, H.J.; Ohmart, C.P.; Wylie, F.R. 1998. Insect pests of Australian forests. Inkata Press, Melbourne. 214 p.

French, J.R.J. 1986. Termites and their economic importance in Australia. Pp. 103-129. In: Vinson, S.B., ed. Economic impact and control of social insects. Praeger: New York.

Gay, F.J. 1969. Species introduced by man. Pp. 459-494. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Gay, F.J.; Calaby, J.H. 1970. Termites of the Australian Region. Pp. 393-448. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Greaves, T. Termites as forest pests. Australian Forestry 23:114-120.

Greaves, T.; McInnes, R.S.; Dowse, J.E. 1965. Timber losses caused by termites, decay, and fire in an alpine forest in New South Wales. Australian Forestry 29:161-174.

Haverty, M.I.; Woodrow, R.J.; Nelson, L.J.; Grace, J.K. 2000. Cuticular hydrocarbons of termites of the Hawaiian Islands. Journal of Chemical Ecology 26:1167-1191.

Miller, E.M. 1969. Caste differentiation in the lower termites. Pp. 283-310. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Minko, G. 1965. Termites in living *Pinus radiata*. Forests Commission Victoria, Forestry Technical Papers 15:1-3.

Paton, R.; Creffield, J.W. 1987. The tolerance of some timber insect pests to atmospheres of carbon dioxide and carbon dioxide in air. International Pest Control 29:10-12.

Peters, B.C.; King, J.; Wylie, F.R. 1996. Pests of timber in Queensland. Queensland Forestry Research Institute, Department of Primary Industries, Queensland.

Thorne, B.L.; Carpenter, J.M. 1992. Phylogeny of the Dictyoptera. Systematic Entomology 17:253-268.

Woodrow, R.J.; Grace, J.K.; Yates, J.R. III. 1999. Hawaii's termites – an identification guide. Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, HSP-1. 6 p.

Reviewers' Comments

None received.

DRYWOOD TERMITES

Assessor—Michael Haverty

Scientific name of pest—Drywood termites (Isoptera: Kalotermitidae) are represented by six genera: *Neotermes* Holmgren [specifically *N. insularis* (Walker)], *Kalotermes* Hagen [specifically *K. rufinotum* Hill and *K. banksiae* Hill], *Ceratokalotermes* Krishna [specifically *C. spoliator* (Hill)], *Glyptotermes* Froggatt [specifically *G. tuberculatus* Froggatt], *Bifiditermes* Krishna [specifically *B. condonensis* (Hill)], and *Cryptotermes* Banks [specifically *Cryptotermes primus* Hill, *C. brevis* (Walker), *C. domesticus* (Haviland), *C. dudleyi* Banks, and *C. cynocephalus* Light]

Scientific names of hosts—Just about any hardwood or softwood species can be infested.

Distribution—*Neotermes insularis* is the only species of this genus in Australia. Its distribution extends from Victoria to Torres Strait and across to Darwin, Northern Territory, and it has been introduced into New Zealand, apparently in shipments of hardwood poles. However, *N. insularis* is not considered to be established in New Zealand. All reports of this species in New Zealand concern imported Australian hardwood poles, some of which have been in service for up to 20 years. No infestations have been found in locally grown (New Zealand) material (Bain and Jenkin 1983). Almost all collections of this species are from forests within 80 km of the coast (Gay and Calaby 1970, French 1986). *Kalotermes rufinotum* is distributed from Victoria to southern Queensland. *Kalotermes banksiae* occurs in Victoria,

New South Wales, and South Australia, and has also been recorded from New Zealand (Gay and Calaby 1970, Bain and Jenkin 1983, French 1986). *Ceratokalotermes* is a genus that is endemic to Australia. *C. spoliator* is the only species in this genus and occurs in the coastal and adjacent highland areas from New South Wales to northern Queensland (Gay and Calaby 1970). *Glyptotermes tuberculatus* occurs in New South Wales and has been introduced to New Zealand, but is not established there (Gay and Calaby 1970, Bain and Jenkin 1983). *Bifiditermes condonensis* is the only Australian species of this genus. It is distributed in coastal areas from southern Queensland to Western Australia and has been collected from low-rainfall areas (< 30 cm/year), an unusual habitat for kalotermitids in Australia (Gay and Calaby 1970). *Cryptotermes primus* is found from northern Queensland to southern New South Wales (Gay and Calaby 1970). *Cryptotermes domesticus*, *C. dudleyi*, and *C. cynocephalus* are found in northern Queensland; *Cryptotermes domesticus* has also been reported from the Australian Capital Territory. *Cryptotermes domesticus* occurs widely throughout the Indo-Malayan Region and in numerous islands and island groups over a wide area of the Pacific, but its exact origin is not known. It has been introduced into Panama and Guam (Gay 1969). *Cryptotermes cynocephalus* is endemic to the Philippine Islands, where it attacks isolated boards in houses, and has recently been reported established in Hawaii (Woodrow et al. 1999, Haverty et al. 2000). *Cryptotermes brevis* is a cosmopolitan species, has been reported from Queensland and New South Wales, and has become established in numerous

regions throughout the world (Gay 1969, Weesner 1970, French 1986, Peters et al. 1996); it has had significant economic impact in Hawaii and Florida (Bess 1970, Weesner 1970, Su and Scheffrahn 1990).

Summary of natural history and biology of the pest—Of the 2,300 species of termites known to exist in the world, only 183 are known to cause damage to structures, and of these, 83 have a significant economic impact. Drywood termites account for less than 20 percent of the economically significant species, and the genus *Cryptotermes* contains the largest number of economically significant species (Gay 1969, Edwards and Mill 1986).

Drywood termites live entirely within wood, do not need to maintain a connection with the ground or soil, and do not absolutely require free water. In fact, some species, such as *C. brevis*, do not survive under conditions of high relative humidity or water content in the wood (Collins 1969): this species produces metabolic water from wood and cannot excrete enough water to survive under high humidity. Most drywood termites are heavily protected from water loss by cuticular hydrocarbons and the cement layer on the cuticle. They adjust their water retention or excretion by absorbing water from their feces (Haverty et al. 2005). In high humidity conditions, they excrete liquid fecal material; under dry conditions, water is resorbed in the rectum and fecal material is excreted as a pellet (Collins 1969). Due to their ability to survive in wood with little moisture content, drywood termites can maintain viable colonies or portions of colonies for extended periods, and these colonies would remain viable during transportation across vast stretches of land or water.

All species of drywood termites are social insects and live in colonies. They do not live in discrete nest structures, but in a diffuse gallery system entirely within one or more pieces of wood. Individuals within this gallery system, including the reproductives, are mobile and can move within this system to areas with the most suitable environmental conditions. Generally there are five types of individuals in a colony: immatures or larvae, workers, soldiers, reproductives, and nymphs (Miller 1969). Nymphs will eventually metamorphose into adults with wings (alates) and serve to disperse and establish new colonies a significant distance (about 100 m) from the natal colony. Colonies contain a large proportion of workers and nymphs, whose role is the care of the immatures, feeding and foraging, and cleaning, whereas the soldiers defend the colony from predators. The workers and younger nymphs are the individuals that damage the wood. Flights of the future reproductives (alates) can occur anytime during the year in tropical environments.

Mature colonies can contain up to several thousand individuals, but even mature colonies never reach the size of mature subterranean termite colonies (Mampe 1990, Thorne 1998). Colonies as young as four years old can produce alates that fly off to establish new colonies. Incipient colonies can reinfest the same piece of wood occupied by the natal colony or other suitable wood nearby. To initiate a new colony, alates need only find a gap or hole big enough for them to enter, seal off, and begin to excavate. Most

drywood species in Australia establish colonies in dead wood on trees, within branch stubs, or in wounds or scars in the bark. Occasionally, the exit holes of wood-boring beetles are utilized to establish an incipient colony site. Colonies can be established low on the bole or high into the canopy of trees (Gay and Calaby 1970). Wood species is not a critical factor for pest species of drywood termites. Many drywood species utilize seasoned wood as host material (Mampe 1990, Peters et al. 1996). Workers and nymphs are capable of becoming replacement (neotenic) reproductives and assuming the reproductive role if the reproductives die or a portion of the colony is permanently separated from the main colony. It is this capacity for establishing new colonies from partial colonies or subcolonies that makes drywood termites a threat for introduction into non-endemic sites.

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest(s) with host-commodity at origin potential:

   Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*, *e*, *f*, *g*, *h*.
   Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

   Any of the commercial *Pinus* species could supply harborage for drywood termites. The likelihood of association of drywood termites with freshly cut logs is greater in older trees grown in plantations in

which silvicultural practices include pruning and use of prescribed fire. The damage done by these termites may not be easily detected in logs. Termites would not survive the chipping process.

2. Entry potential:

   Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*.
   Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

   Drywood termites could survive quite well during transit and may not be detected if they are within the wood. The most likely indication of the presence of drywood termites would be piles of characteristic fecal pellets on horizontal surfaces, but these pellets are usually not discharged until colonies are well established in the wood. The greatest danger exists if items are shipped from plantations in Australia with these species present and remain in storage at the import site, in a suitable habitat such as Hawaii or Puerto Rico, for extended periods of time. Wood chips are not likely to harbor viable groups of termites.

3. Colonization potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*.

   Even partial colonies can contain many individuals capable of differentiating into a reproductive caste. If a colony contains alates and they were to fly after arriving in the United States, incipient colonies could easily be established. Because

these drywood termites can infest numerous tree species and wood in use, the presence of an acceptable host is not the critical factor. Rather, a suitable environment with an adequate supply of wood and appropriate temperature and moisture conditions are the key factors. The initiation of a colony is a slow process, but dry wood in structures and suitable trees with scars or wounds at ports and storage facilities might provide an infestation site. The adults (alates) fly only about 100 m, but are capable of moving up to 1 km depending on wind conditions and weather. Long-range (> 10km) establishment of colonies from alates has a very low probability. Colonization potential is greatest at ports with warm, moist conditions, such as those in Hawaii, southern California, the Gulf Coast, and the southern Atlantic coast.

4. Spread potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*, *g*.

   Termites spread slowly (15 to 300 m per year), and less than 1 percent of the alates eventually establish a new colony. However, an important factor concerning drywood termites is that infested wood, moved by humans in commerce, spreads termites at a much faster rate than their natural spread. Also, once established at the receiving seaport or inland destinations, drywood termites are often not detected because of their cryptic habits; colonies can be large before the first evidence of their activities (piles of characteristic fecal pellets)

is apparent. By this time, multiple colonies will already be established adjacent to the invading colony, and additional wood or trees could become infested and distributed within the continental United States or its territories and possessions. Furthermore, drywood termites could be misdiagnosed or confused with endemic species.

B. Consequences of introduction

5. Economic damage potential: *Moderate* (VC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*.

   Termites will attack untreated wood. Their damage to wooden houses can be severe if not detected at an early stage. Once they are in a structure, spread of drywood termites to other parts of the structure can be rapid and its economic impact can be quite high. Most species of *Cryptotermes* probably would not do well in extremely cold climates, but could be a problem in moist, warm climates along the western, southern, and southeastern coasts of the continental United States. Drywood termites cause a small portion of the economic losses due to wood-destroying insects in the United States. However, where they are abundant (Florida, California, and Hawaii), the costs for control and repair of their damage rivals that of subterranean termites. Potential economic losses caused by all species of *Cryptotermes* could be comparable with those currently caused by the exotic *C. brevis* and the endemic *Incisitermes minor* (Hagen). If *C. primus or C. domes-*

ticus were to be as aggressive as *C. brevis* and *I. minor*, it could cause an additional $100 million in damage and control costs within 30 years. Control methods for termites are available, but can be expensive.

6. Environmental damage potential: *Low* (MC). Applicable rating criteria from Chapter 1: none.

    These termites would not likely cause large outbreaks or kill an excessive number of trees. Drywood termites would most likely feed on dead wood in live trees or dead wood on the ground. Control efforts could be a risk to environmental quality through increased pesticide use.

7. Social and political considerations: *Moderate* (RC). Applicable rating criterion from Chapter 1: *a*.

    Drywood termites do not cause aesthetic damage in forests. They can infest live trees by attacking pruning and fire scars. This could degrade the value of timber species grown where drywood termites live. Damage to wood in use would cause the consumer the greatest concern, adding to concerns about other termite species. Control methods for termites are available but can be expensive. Spot treatments do not eliminate the problem; fumigant gases stop the infestation, but provide no residual protection. Furthermore, one of the fumigant gases (methyl bromide) is being phased out of product due to concerns over adverse effects to environmental quality through depletion of the ozone layer.

Any species of *Cryptotermes* becoming successfully established in the United States or in one of its protectorates or possessions would probably be as damaging as *C. brevis* or *I. minor*.

C. Pest risk potential

   Logs – *High* (Likelihood of introduction = *High*; Consequences of introduction = *Moderate*).

   Chips – *Low* (Likelihood of introduction = *Low*; Consequences of introduction = *Moderate*).

Selected Bibliography

Bain, J.; Jenkin, M.J. 1983. *Kalotermes banksiae*, *Glyptotermes brevicornis*, and other termites (Isoptera) in New Zealand. New Zealand Entomologist 7:365-371.

Bess, H.A. 1970. Termites of Hawaii and the oceanic islands. Pp. 449-476. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Collins, M.S. 1969. Water relations in termites. Pp. 433-458. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Edwards, R.; Mill, A.E. 1986. Termites in buildings. their biology and control. East Grinstead: Rentokil Limited. 261 p.

French, J.R.J. 1986. Termites and their economic importance in Australia. Pp. 103-129. In: Vinson, S.B., ed. Economic impact and control of social insects. Praeger: New York.

Gay, F.J. 1969. Species introduced by man. Pp. 459-494. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Gay, F.J.; Calaby, J.H. 1970. Termites of the Australian Region. Pp. 393-448. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Haverty, M.I.; Woodrow, R.J.; Nelson, L.J.; Grace, J.K. 2000. Cuticular hydrocarbons of termites of the Hawaiian Islands. Journal of Chemical Ecology 26:1167-1191.

Haverty, M.I.; Woodrow, R.J.; Nelson, L.J.; Grace, J.K. 2005. Identification of termite species by the hydrocarbons in their feces. Journal of Chemical Ecology 31:2119-2151.

Mampe, C.D. 1990. Termites. Pp. 201-262. In: Mallis, A., ed. Handbook of pest control: the behavior, life history and control of household pests. Cleveland, OH, Franzak and Foster, Co.

Miller, E.M. 1969. Caste differentiation in the lower termites. Pp. 283-310. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Peters, B.C.; J. King, J.; Wylie, F.R. 1996. Pests of timber in Queensland. Queensland Forestry Research Institute, Department of Primary Industries, Queensland. 175 p.

Su, N.-Y.; Scheffrahn, R.H. 1990. Economically important termites in the United States and their control. Sociobiology 17(1):77-94.

Thorne, B.L. 1998. Biology of subterranean termites of the genus *Reticulitermes*. Pp. 1-30. In: NPCA research report on subterranean termites. Dunn Loring, VA: National Pest Control Association.

Weesner, F.M. 1970. Termites of the Nearctic Region. Pp. 477-525. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Woodrow, R.J.: Grace, J.K.; Yates, J.R. III. 1999. Hawaii's termites – an identification guide. Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, HSP-1. 6 p.

Reviewers' Comments

None received.

Subterranean Termites

Assessor—Michael Haverty

Scientific name of pest—Subterranean termites (Isoptera: Rhinotermitidae and Termitidae) in the genera *Schedorhinotermes* Silvestri [specifically *Schedorhinotermes intermedius intermedius* (Brauer), *S. i. actuosus* (Hill), *S. i. breinli* (Hill), *S. i. seclusus* (Hill), and *S. reticulatus* (Froggatt)], *Heterotermes* Froggatt [specifically *Heterotermes ferox* (Froggatt), and *H. paradoxus* (Froggatt)], *Coptotermes* Wasmann [specifically *Coptotermes acinaciformis* (Froggatt), *C. frenchi* Hill, *C. lacteus* (Froggatt), and *C. raffrayi* Wasmann], *Microcerotermes* Silvestri [specifically *Microcerotermes boreus* Hill, *M. distinctus* Silvestri, *M. implicadus* Hill, *M. nervosus* Hill, and *M. turneri* (Froggatt)], and *Nasutitermes* Dudley [specifically *Nasutitermes exitiosis* (Hill)]

Scientific names of hosts—Just about any hardwood or softwood could be infested.

Distribution—*Schedorhinotermes*, *Heterotermes*, *Coptotermes, Microcerotermes*, and *Nasutitermes* are all pantropical genera. Many of the individual taxa in these genera are difficult to identify. The taxonomy of several of the subterranean genera in Australia is in desperate need of taxonomic revision (Gay and Calaby 1970, Watson et al. 1989, Brown et al. 1994). Light (1927) suggested that several factors make species determinations in termites difficult. First, termites are practically lacking in ornamentation and have few definite differences in position or number of parts that facilitate species diagnosis. Second, termite species are extremely plastic and exhibit a wide range of variation, both from region to region and among colonies within the same region. Third, the characters that prove useful are differences in range of size of parts or of the entire individual or differences in size relations (i.e., in the proportions of parts), which characteristics can be subjective. Definitive species determinations of the Australian fauna will require the use of modern diagnostic techniques, such as characterization of cuticular hydrocarbons (Brown et al. 1996) or cladistics (Miller 1997). Therefore, the distributions reported in the literature for a given species may, in fact, represent a combined distribution of sibling species with either sympatric, parapatric, or allopatric distributions.

In Australia *Schedorhinotermes* is represented by two species, one of which is made of up to four subspecies. *Schedorhinotermes intermedius intermedius* occurs from New South Wales into southern Queensland. *Schedorhinotermes intermedius actuosus* occurs in all of the mainland states except Victoria. *Schedorhinotermes intermedius breinli* is present in Queensland and the Northern Territory and is abundant in arid inland districts and areas of low rainfall near the coast. *Schedorhinotermes intermedius seclusus* extends from northern New South Wales to north Queensland. *Schedorhinotermes reticulatus* is widely distributed on the mainland, but appears to be absent from the Northern Territory (Gay and Calaby 1970, French 1986).

Heterotermes ferox extends from southern Queensland through southeastern and southern areas of mainland Australia across to Western Australia. All four subspecies of *Heterotermes paradoxus*

are distributed mainly in northern Australia (Gay and Calaby 1970, French 1986).

Coptotermes is represented by at least six species in Australia and is widely distributed throughout the mainland. With the exception of one species, the genus is largely dependent on eucalypts for food; *Coptotermes* species are found in abundance only in eucalypt communities. *Coptotermes acinaciformis* is widely distributed throughout Australia, but is absent from alpine areas of southeastern Australia and from Tasmania. It shows a wide tolerance of climatic conditions and has been collected from localities with annual rainfall ranging from as low as 20 cm up to more than 150 cm. The putative subspecies *Coptotermes acinaciformis raffrayi* occurs only in southwestern Australia. *Coptotermes frenchi* extends from north Queensland to Western Australia in eucalypt communities. *Coptotermes lacteus* is very common in eastern Australia, from Victoria to southern Queensland (Gay and Calaby 1970, French 1986).

Microcerotermes species are found all over mainland Australia with the exception of the southeastern portion of the continent. *Microcerotermes boreus* is confined to the northwest of Western Australia and the Northern Territory. *Microcerotermes distinctus* is widely distributed in all mainland states, more particularly in drier inland areas. *Microcerotermes implicadus* is distributed from southern Queensland through Victoria. *Microcerotermes nervosus* is common in the northern parts of Western Australia and the Northern Territory. *Microcerotermes turneri* is restricted to coastal districts from central New South Wales to north Queensland (Gay and Calaby 1970, French 1986).

Nasutitermes, which has 19 currently described species from Australia, is one of the most successful genera in Australia and one of the few that has penetrated the cool temperate southeastern portion of the continent. *Nasutitermes exitiosus* is the best known species of the genus. It extends from southern Queensland around the southeastern and southern regions of the continent across to Western Australia. Over most of its range, its northern limit of distribution coincides with the boundary of eucalypt communities. *Nasutitermes exitiosus* is absent from the wetter coastal country and from the colder higher parts of the southern highlands (Gay and Calaby 1970, French 1986).

Summary of natural history and biology of the pest—Subterranean termites must maintain a connection with the ground or soil unless a supply of water is otherwise available. When free water is available or wood is saturated with water, species in these genera can maintain viable colonies or portions of colonies for extended periods and remain alive during transportation across vast stretches of land or water. They can also establish aerial colonies in buildings. To attack wood above the ground, shelter tubes composed of wood, soil, and termite excrement are constructed to connect the colony from the soil to the source of wood they are exploiting (Mampe 1990, Thorne 1998).

All species of subterranean termites are social insects and live in colonies. Some species of *Coptotermes* are found in discrete nest structures and can con-

struct mounds. *Heterotermes* and *Schedorhinotermes*, as well as some species of *Coptotermes*, live in diffuse nests, a dispersed aggregation of subnests. These subnest units are mobile and allow the entire colony, including the reproductives, to move to areas with the most suitable environmental conditions (Thorne 1998). Generally there are five types of individuals in a colony: immatures or larvae, workers, soldiers, reproductives, and nymphs (Miller 1969). Nymphs will eventually metamorphose into adults with wings (alates) and serve to disperse and establish new colonies a significant distance from the natal colony. Colonies contain a large proportion of wingless workers whose role is the care of the immatures, feeding and foraging, and cleaning, whereas the soldiers defend the colony from predators. The workers are the individuals that damage the wood. Flights of the future reproductives (alates) generally occur during spring, summer, or fall after rain, but can occur anytime during the year in tropical environments.

Mature colonies contain several thousands to millions of individuals (Thorne 1998). Satellite colonies of the larger colonies can also be of a size that is equivalent to an immature or young colony. Workers and nymphs are capable of becoming replacement reproductives and assuming the reproductive role if their satellite colony or subunit is permanently separated from the main colony. It is primarily this capacity for establishing new colonies (by budding) from satellite colonies or subcolonies that makes subterranean termites a threat for introduction from nonendemic sites.

Coptotermes species generally occur in tropical or subtropical areas, and numerous species are known to infest buildings. *Coptotermes formosanus* Shiraki and *C. havilandi* (Sjöstedt) have most frequently been introduced to new localities (Edwards and Mill 1986). Where these species occur in exotic locations, they cause extensive damage to buildings. *Coptotermes formosanus* was first discovered in the Hawaiian Islands in 1907 (Bess 1970) and on the mainland of the United States in 1965 (Weesner 1970), but was likely established many years before both in Hawaii and on the mainland of the United States. *Coptotermes formosanus* has recently become successfully established in La Mesa near San Diego, California (Rust et al. 1998), and *C. havilandi* has recently been reported to be established in Florida (Su et al. 1997). *Coptotermes acinaciformis* and *C. frenchi* have become established in New Zealand, likely introduced from Australia in imported logs (Bain and Jenkin 1983). *Coptotermes formosanus*, *C. havilandi*, *C. acinaciformis*, and *C. frenchi* often feed on live trees and may eventually kill them, or damage the root system, causing the trees to fall in heavy winds. *Coptotermes lacteus* feeds primarily on wood on the ground or wood in contact with the ground. *Schedorhinotermes, Heterotermes, Microcerotermes,* and *N. exitiosus* also feed on wood in contact with the ground, but will bridge gaps with foraging tubes to reach wood above ground. Recently, a species of *Microcerotermes* has been discovered in San Diego County, California, further indicating that species of this genus could become established in North America (Setter and Myles 2005). Likewise, *Nasutitermes costalis* has been introduced

and established in Florida (Scheffrahn et al. 2002). For the purposes of this assessment, all species of *Heterotermes* and *Coptotermes* should be considered dangerous if arriving at U.S. ports.

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest(s) with host-commodity at origin potential:

   Logs – *High* (VC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*.
   Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

   Just about any of the commercial pine species could supply harborage for subterranean termites. The likelihood of association of subterranean termites with freshly cut logs is much greater in plantations in which silvicultural practices include precommercial thinning and use of prescribed fire. Trees infested by bark beetles could easily be attacked and infested by subterranean termites. Logs stacked after harvest and left in place for several months would also be susceptible. Damage done by subterranean termites would likely be under the bark and easily detected. These logs should be redirected to a chip mill rather than being shipped overseas as whole logs. Termite colonies or subcolonies would not survive the chipping process, the process of moving the chips from the mill to the ship, or from the ship to the processing plant.

2. Entry potential:

   Logs – *High* (RC). Applicable rating criteria from Chapter 1: *a*, *c*.
   Chips – *Low* (RC). Applicable rating criteria from Chapter 1: none.

   Viable colonies of various subterranean termite species would likely survive the 14-day journey to port cities in the United States, although they should be detectable within logs by the presence of foraging tubes or an extensive gallery system under the bark. Recently cut logs with bark beetle galleries would provide conditions suitable to subterranean termites during transit. The greatest introduction danger exists if logs are shipped from Australia with subterranean species present and then remain in storage at the import site for extended periods of time. This is how *C. acinaciformis* and *C. frenchi* became established in New Zealand. Wood chips are not likely to harbor viable groups of termites.

3. Colonization potential: *High* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *c*, *d*, *e*.

   Coptotermes acinaciformis and C. frenchi have become established in New Zealand, and *C. formosanus*, *C. havilandi*, and *C. vastator* Light have become established in exotic locations (Gay 1969, Su and Scheffrahn 1998a). *Nasutitermes* species have been intercepted upon introductionprior to being established (Gay 1969). Not one of the subterranean termites examined in this report is restricted by host. Even partial colonies can contain many

individuals capable of differentiating into a reproductive caste. If a colony contains alates and they were to fly after arriving in the United States, incipient colonies could easily be established. Because these subterranean termites can infest numerous tree species and wood in use, the presence of an acceptable host is not the critical factor. Rather, a suitable environment with an adequate supply of wood and appropriate temperature and moisture conditions are the key factors. The initiation of a colony is a slow process, but wood in ground contact, moist wood in structures, and suitable host trees with scars or wounds at ports and storage facilities may provide an infestation site. The adults (alates) fly only about 100 m, but are capable of moving up to 1 km depending on wind conditions and weather. Long-range (> 10km) establishment of colonies from alates has a very low probability. Colonization potential would depend on the genus; warm, moist conditions would be conducive to *Heterotermes, Coptotermes*, and *Schedorhinotermes*, and cool, moist conditions would likely favor *N. exitiosus*.

4. Spread potential: *High* (RC). Applicable rating criteria from Chapter 1: *b, c, d, e, f, g.*

   Termites spread slowly (15 to 300 m per year), and less than 1 percent of the alates eventually establish a new colony. However, an important factor concerning subterranean termites is that movement of infested wood (or plants in soil) by humans in commerce spreads termites at a much faster rate than their natural spread. Also, once established at the receiving seaport or inland destinations, subterranean termites are often not detected because of their cryptic habits; colonies can be large before the first evidence of their activities is apparent. By this time, multiple colonies can already be established adjacent to the invading colony, and additional wood or plants could become infested and distributed within the continental United States or its possessions. Furthermore, exotic subterranean termite infestations could be misdiagnosed or confused with endemic species.

B. Consequences of introduction

   5. Economic damage potential: *High* (VC). Applicable rating criteria from Chapter 1: *a, b, c, f.*

   Of the 2,300 species of termites known to exist in the world, only 183 are known to cause damage to structures, and of these, 83 have a significant economic impact. Subterranean termites account for about 80 percent of the economically important species (Gay 1969, Su and Scheffrahn 1990), and the genus *Coptotermes* contains the largest number of economically important species (Su and Scheffrahn 1998b). Of the 183 species noted for their potential for economic damage, only 17 occur in the United States (Su and Scheffrahn 1990). Control of subterranean termites and repair of their damage in the United States results in a total economic impact of

about $6.0 billion (billion = X10^9) per year [$1.5 to 2.0X10^9 for control of subterranean termites and $4X10^9 for repair of damage] (Nan-Yao Su, University of Florida, Ft. Lauderdale, FL, 1999, pers. comm.).

Subterranean termites will attack untreated wood and some will attack live trees. None of these termites discussed here would do well in extremely cold climates, but could be a problem in moist, warm climates along the western, southern, and southeastern coasts of the continental United States and in subtropical and tropical locations of the United States and its protectorates and possessions. They could pose a significant hazard to the numerous *Eucalyptus* trees planted as ornamentals, as windbreaks, or for fiber. Control methods for subterranean termites are available, but can be expensive and could be a risk to environmental quality through increased pesticide use. The exotic *Coptotermes formosanus* Shiraki is out of control in New Orleans, Louisianna. In some situations it can be controlled or managed with baits, however, in the French Quarter, it has proven very difficult to control. Given that some of the species of *Coptotermes* in Australia occur in temperate climates, they could easily become established in the United States and perhaps confused with *C. formosanus*.

6. Environmental damage potential: *Moderate* (MC). Applicable rating criterion from Chapter 1: *d*.

These termites would not likely cause large outbreaks or kill an excessive number of trees. Trees at greatest risk would be street trees, such as the ones injured by *C. formosanus* in Honolulu and New Orleans. They could conceivably compete with native termites that degrade and decompose wood in use. In fact, where *C. formosanus* is established in Florida and New Orleans, they successfully compete with the native termite fauna.

7. Social and political considerations: *Moderate* (RC). Applicable rating criterion from Chapter 1: *a*.

These termites generally do not cause aesthetic damage in forests, although most *Coptotermes* species will consume the heartwood of live trees. However, damage to wood in use would cause significant consumer concerns, adding to concerns about other exotic termites species already established in the United States.

C. Pest risk potential

Logs – *High* (Likelihood of introduction = *High*; Consequences of introduction = *High*).

Chips – *Low* (Likelihood of introduction = *Low*; Consequences of introduction = *High*).

Selected Bibliography

Bain, J.; Jenkin, M.J. 1983. *Kalotermes banksiae*, *Glyptoterems brevicornis*, and other termites (Isoptera) in New Zealand. New Zealand Entomologist 7:365-370.

Bess, H.A. 1970. Termites of Hawaii and the oceanic islands.) Pp. 449-476. In Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press

Brown, W.V.; Watson, J.A.L.; Lacey, M.J. 1994. The cuticular hydrocarbons of workers of three Australian *Coptotermes* species, *C. michaelseni*, *C. brunneus* and *C. dreghorni* (Isoptera: Rhinotermitidae). Sociobiology 23:277-291.

Brown, W.V.; Watson, J.A.L.; Lacey, M.J. 1996. A chemosystematic survey using cuticular hydrocarbons of some species of the Australian harvester termite genus *Drepanotermes* (Isoptera: Termitidae). Sociobiology 27:199-221.

Edwards, R.; Mill, A.E. 1986. Termites in buildings. Their biology and control. East Grinstead: Rentokil Limited. 261 p.

French, J.R.J. 1986. Termites and their economic importance in Australia. Pp. 103-129. In Vinson, S.B., ed. Economic impact and control of social insects. Praeger: New York.

Gay, F.J. 1969. Species introduced by man. Pp. 459-494. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Gay, F.J.; Calaby J.H. 1970. Termites of the Australian Region. Pp. 393-448. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Light, S.F. 1927. A new and more exact method of expressing important specific characters of termites. Univ. California Publ. Entomol. 4:75-88.

Mampe, C.D. 1990. Termites. Pp, 201-262. In: Mallis, A., ed. Handbook of pest control. The behavior, life history and control of household pests. Cleveland, OH: Franzak and Foster, Co.

Miller, E.M. 1969. Caste differentiation in the lower termites. Pp. 283-310. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Miller, L.R. 1997. Systematics of the Australian Nasutitermitinae with reference to evolution within the Termitidae (Isoptera). Ph.D. Thesis, Australian National University, Canberra, ACT, Australia. 170 p.

Rust, M.K.; Reierson, D.A.; Paine, E.O.; Kellum, K.; Haagsma, K. 1998. Ravenous Formosan subterranean termite persists in California. California Agriculture 52:34-37.

Scheffrahn, R.H.; Cabrera, B.J.; Kern, W.H., Jr.; Su, N.-Y. 2002. *Nasutitermes costalis* (Isoptera: Termitidae) in Florida: first record of a non-endemic establishment by a higher termite. Florida Entomologist 85:273-275.

Setter, R.R.; Myles, T.G. 2005. First record of *Microcerotermes* (Isoptera: Amitermitinae: Termitidae) from the continental United States, with observations on its unique ecology. American Entomologist 51:96-103.

Su, N.-Y.; Scheffrahn, R.H. 1990. Economically important termites in the United States and their control. Sociobiology 17(1):77-94.

Su, N.-Y.; Scheffrahn, R.H.; Weissling, T. 1997. A new introduction of a subterranean termite, *Coptotermes havilandi* Holmgren (Isoptera: Rhinotermitidae), in Miami, Florida. Florida Entomologist 80(3):408-411.

Su, N.-Y.; Scheffrahn, R.H. 1998a. *Coptotermes vastator* Light (Isoptera: Rhinotermitidae) in Guam. Proc. Hawaiian Entomol. Soc. 33:13-18.

Su, N.-Y.; Scheffrahn, R.H. 1998b. A review of subterranean termite control practices and prospects for integrated pest management programmes. Integrated Pest Management Reviews 3(1):1-13.

Thorne, B.L. 1998. Biology of subterranean termites of the genus *Reticulitermes*. Pp. 1-30. In: NPCA research report on subterranean termites. Dunn Loring, VA: National Pest Control Association.

Watson, J.A.L.; Brown, W.V.; Miller, L.R.; Carter, F.L.; Lacey, M.J. 1989. Taxonomy of *Heterotermes* (Isoptera: Rhinotermitidae) in southeastern Australia: cuticular hydrocarbons of workers, and soldier and alate morphology. Systematic Entomology 14:299-325.

Weesner, F.M. 1970. Termites of the nearctic region. Pp. 477-525. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Reviewers' Comments

None received.

PATHOGEN IPRAS

DIPLODIA SHOOT BLIGHT

Assessor—John Kliejunas

Scientific name of pest—*Sphaeropsis sapinea* (Fr.:Fr.) Dyko & Sutton [*Diplodia pinea* (Desmaz.) J. Kickx fil.] (Coelomycetes)

Scientific names of hosts—*Pinus radiata* in Australia; *Abies* spp. (*A. alba*, *A. procera*), *Araucaria* spp., *Chamaecyparis lawsoniana*, *Cedrus* spp., *Cupressus* spp., *Juniperus* spp., *Larix laricina*, *Picea* spp. (*P. pungens*, *P. sitchensis*), *Pinus* spp. (*P. canariensis*, *P. contorta*, *P. elliottii*, *P. mugo*, *P. nigra*, *P. palustris*, *P. patula*, *P. ponderosa*, *P. radiata*, *P. resinosa*, *P. strobus*, *P. sylvestris*, *P. taeda*), *Pseudotsuga macrocarpa*, *P. mensiesii*, and *Thuja* spp. in other countries.

Distribution—Australia (Australian Capitol Territory, New South Wales, Queensland, South Australia, Tasmania, Victoria, Western Australia), Canada, Central America, South America, Europe, Africa, Asia, New Zealand, Mexico, and the United States.

Summary of natural history and basic biology of the pest—*Sphaeropsis sapinea* is a cosmopolitan, opportunistic pathogen associated with a wide range of coniferous hosts (Swart and Wingfield 1991). It causes a stem and foliage disease that can result in defoliation, dieback, shoot blight, cankers, and mortality (Peterson 1982). Root infection has been reported in South Africa (Wingfield and Knox-Davies 1980). Infection of shoot tips results in stunting, yellowing, and curling of the tips. Infection occurs directly in unwounded, succulent shoots as they are expanding in the spring. Stems become infected through wounds caused by hail, insects, or other wounding agents. A blue to black stain of the wood is often associated with stem infection (Aguilar 1985, Chou and MacKenzie 1988). Collar rot results when the pathogen invades tissue in the root collar area.

The pathogen readily fruits on diseased tissue, slash, and cones (Peterson 1981). Fruiting bodies (pycnidia) of the fungus form at the base of the stunted, current year needles in late summer or fall. The fruiting structures are also formed on the scales of two-year-old cones. The fungus overwinters on dead needles, on bark, and on wood and cones. During wet spring weather, spores are produced and spread by wind or rain splash to young needles and buds. Spread occurs primarily by rain splash of the spores (Peterson 1981), but spores can also be distributed by air currents. Germinating conidia invade new buds or new needles by stomatal penetration or through wounds. Second year seed cones may also become infected. Dieback symptoms appear several weeks or more after infection. The fungus is capable of acting as an endophyte, existing in living tissue without causing symptoms (Smith et al. 1996, Stanosz et al. 1997), and as a saprophyte, colonizing dead needle tissue.

In Australia, *Sphaeropsis sapinea* has been reported on *P. radiata*. The fungus has seriously damaged extensive exotic plantations of *P. radiata* in Australia, New Zealand, and South Africa (Peterson 1982). Infection intensity varies with environmental and host conditions. Outbreaks are associated with stress conditions such as drought, and physical damage caused by insects, hail, and other

agents. Dieback tends to decrease with increasing tree size (Chou 1976a and b, Gibson 1979).

Sphaeropsis sapinea is a highly variable species. Although Chou (1976b) did not find differences in pathogenicity or virulence among 18 New Zealand isolates, others have found differences among isolates in cultural characteristics, conidial size and morphology, and pathogenicity (Wang et al. 1985, Palmer et al. 1987, Swart et al. 1988). Two distinct types of *S. sapinea*, denoted Types A and B, were identified from north central United States (Palmer et al. 1987) based on conidial morphology and cultural characteristics and confirmed using randomly amplified polymorphic DNA (RAPD) markers (Smith and Stanosz 1995). On red pine (*P. resinosa* Aiton) isolates of the A morphotype are more aggressive than isolates of the B morphotype (Blodgett and Stanosz 1997). De Wet et al. (2000) described a 'C' morphotype of *S. sapinea* from a collection of isolates from Sumatra based on spore morphology, RAPDs, and ITS sequence data. An 'I' morphotype was identified among Canadian isolates of the fungus (Hausner et al. 1999). These 'I" isolates were later found to be identical to *Botryosphaeria obtusa* using simple sequence repeat (SSR) markers (Burgess et al. 2001). The general pattern of isozymic diversity reflects relatively high levels of genetic variation within local populations, but a lack of sharp dissimilarity between geographic populations (Swart et al. 1992). The fungus may be a highly variable species that represents a continuum without defined types or strains (Swart and Wingfield 1991).

Any differences in strain characteristics must be determined between any strains that might be introduced and those already present in the United States. If the strains are the same, then there is no additional pest risk. However, it is known that the North American strains are significantly different among themselves (Palmer et al. 1987) and that differences also exist between an isolate from New Zealand and one from the United States (G. Stanosz, University of Wisconsin, Madison, 1996, pers. comm.).

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

   Logs – *Moderate* (RC). Applicable rating criteria from Chapter 1: *b*, *c*, *e*, *g*.
   Chips – *Low* (RC). Applicable rating criteria from Chapter 1: *b*, *g*.

   The pathogen is common in Australian plantations of *P. radiata*. Because limbs and branches will be removed at harvest, only stem infections will remain on the logs. However, most pines with stem infection will not reach rotation age or be harvested for sawlog export. The normal chipping process removes most of the young shoots and twigs before chipping. Much of the bark, the crevices of which could contain pieces of infected leaf tissue, is also removed before chipping. Therefore, the likelihood of propagules of *S. sapinea* being associated with chips is assessed as "Low."

2. Entry potential:

Logs – *High* (RC). Applicable rating criteria from Chapter 1: *b*, *d*.

Chips – *Low* (VU). Applicable rating criteria from Chapter 1: *d*.

The pathogen could survive transit to the United States in infected needles remaining on any shoots transported with logs or in needles lodged in bark crevices. Points of infection include sapwood, crevices in the bark, and forest floor debris adhering to the logs. Although transit of logs would not affect fungus survival, chipping would reduce chances of survival of the pathogen in the host during transportation. Because the spores of the pathogen are microscopic and would be undetectable, risk criterion *d* would apply. However, the likelihood of propagules of *S. sapinea* being both associated with chips and surviving transport is assessed as "Low."

3. Colonization potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *a*, *b*, *e*.

Pines and other hosts grow near ports of entry. Infection of these hosts would require the development of fruiting bodies of the fungus and subsequent spread of the spores to susceptible tissues. The pathogen has spores that are both waterborne and sometimes windborne that could effectively inoculate susceptible hosts. However, favorable environmental conditions, including moisture and temperature, would need to be present for infection and colonization to occur.

4. Spread potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *a*, *c*, *d*, *g*.

If colonization by *S. sapinea* occurs in native stands, it would spread principally on trees that are stressed and in locations where environmental conditions are conducive for infection. The continuity of hosts in the United States would permit a moderate rate of continual spread.

B. Consequences of introduction

5. Economic damage potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *a*, *c*, *e*.

Sphaeropsis sapinea is present in the United States. It causes damage primarily to ornamental and landscape trees and can be particularly devastating to trees planted off-site. In forest situations, damage is usually scattered and minimal (Sinclair et al. 1987). However, because of the known strain differences and virulence within the species, there is the potential for increased economic damage if a more virulent strain were to be introduced.

6. Environmental damage potential: *Moderate* (RC). Applicable rating criteria from Chapter 1: *f*.

Sphaeropsis sapinea causes significant damage only in stressed trees. Affected trees are commonly localized and widely scattered on poor sites and even in such situations, death rarely occurs (Sinclair et al. 1987). Therefore, the impact on associated ecosystems will be insignificant. However, strains of the

pathogen are genetically different and have varying degrees of virulence. If Australian strains are more virulent than those already present in the United States, the potential for environmental damage would be moderate.

7. Social and political considerations: *Low* (MC). Applicable rating criteria from Chapter 1: none.

Perceived damage potential following successful establishment of *S. sapinea* in new locations as a result of importation would be low. Based on date regarding pathogenicity and virulence of the known strains of the pathogen, further introduction of the species will not cause major impact on forest ecosystems. Thus, the social and political impact should be minimal. However, the introduction of a more virulent strain of this fungus would have greater impact, particularly in ornamental plantings.

C. Pest risk potential

Logs – *Moderate* (Likelihood of introduction = *Moderate*; Consequences of introduction = *Moderate*).

Chips – *Low* (Likelihood of introduction = *Low*; Consequences of introduction = *Moderate*).

The pest risk potential was reduced from "*Moderate*" with logs to "*Low*" with chips. The removal of bark during the chipping process reduces the likelihood of propagules of *S. sapinea* being associated with chips and surviving transport with chips.

Selected Bibliography

Aguilar, A. 1985. Descripción e identificación de organismos asociados al azulado de la madera aserrada en pino isigne (*Pinus radiata* D. Don). Valdivia: Ingeniería Forestal Universidad Ausatral de Chile. Tesis. 67 p.

Blodgett, J.T.; Stanosz, G.R. 1997. *Sphaeropsis sapinea* morphotypes differ in aggressiveness, but both infect nonwounded red or jack pines. Plant Disease 81:143-147.

Burgess, T.; Wingfield, B.W.; Wingfield, M.J. 2001. Comparison of genotypic diversity in natural and introduced populations of *Sphaeropsis sapinea* isolates from *Pinus radiata*. Mycological Research 105:1331-1339.

Burgess, T.; Wingfield, M.J.; Wingfield, B.W. 2001. Simple sequence repeat markers distinguish among morphotypes of *Sphaeropsis sapinea*. Applied and Environmental Microbiology 67:354-362.

Chou, C.K.S. 1976a. A shoot dieback in *Pinus radiata* caused by *Diplodia pinea*. I. Symptoms, disease development, and isolation of pathogen. New Zealand Journal of Forestry Science 6:72-79.

Chou, C.K.S. 1976b. A shoot dieback in *Pinus radiata* caused by *Diplodia pinea*. II. Inoculation studies. New Zealand Journal of Forestry Science 6:409-420.

Chou, C.K.S.; Mackenzie, M. 1988. Effect of pruning intensity and season on *Diplodia pinea* infection of *Pinus radiata* stems through pruning wounds. New Zealand Journal of Forestry Science 12:425-437.

De Wet, J.; Wingfield, M.J.; Coutinho, T.A.; Wingfield, W.D. 2000. Characterization of *Sphaeropsis sapinea* isolates from South Africa, Mexico and Indonesia. Plant Disease 84:151-156.

Gibson, I.A.S. 1979. Diseases of forest trees widely planted as exotics in the tropics and Southern hemisphere. II. The genus *Pinus*. Oxford, England: Commonwealth Mycological Institute, Kew Surrey, and Commonwealth Forestry Institute, University of Oxford. 135 p.

Hausner, G.; Hopkin, A.A.; Davis, C.N.; Reid, J. 1999. Variation in culture and rDNA among isolates of *Sphaeropsis sapinea* from Ontario and Manitoba. Canadian Journal of Plant Pathology 21:256-264.

Palmer, M.A.; Stewart, E.L.; Wingfield, M.J. 1987. Variation among isolates of *Sphaeropsis sapinea* in the north central United States. Phytopathology 77:944-948.

Peterson, G.W. 1981. Control of diplodia and dothistroma blight of pines in the urban environment. Journal of Arboriculture 7:1-7.

Peterson, G.W. 1982. Diplodia blight of pines. Forest Insect and Disease Leaflet 161. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 7 p.

Sinclair, W.A.; Lyon, H.H.; Johnson W.T. 1987. Diseases of trees and shrubs. Ithaca, NY: Cornell University Press. 574 p.

Smith, D.R.; Stanosz, G.R. 1995. Confirmation of two distinct populations of *Sphaeropsis sapinea* in the north central United States using RAPDs. Phytopathology 85:699-704.

Smith, H.; Wingfield, M.J.; Crous, P.W.; Coutinho, T.A. 1996. *Sphaeropsis sapinea* and *Botryosphaeria dothidea* endophytic in *Pinus* spp. and *Eucalyptus* spp. in South Africa. South African Journal of Botany 62:86-88.

Stanosz, G.R.; Smith, D.R.; Guthmiller, M.R.; Stanosz, J.C. 1997. Persistence of *Sphaeropsis sapinea* on or in asymptomatic stems of red pine nursery seedlings. Mycologia 89:525-530.

Swart, W.J.; Wingfield, M.J. 1991. Biology and control of *Sphaeropsis sapinea* on *Pinus* species in South Africa. Plant Disease 75: 761-766.

Swart, W.J.; Wingfield, M.J.; Knox-Davies, P.S. 1988. Relative susceptibility of *Sphaeropsis sapinea* of six *Pinus* spp. cultivated in South Africa. European Journal of Forest Pathology 18:184-189.

Swart, W.J.; Grant, W.S.; Wingfield, M.J. 1992. Allozyme variation among geographic isolates of *Sphaeropsis sapinea*. Abstract. Proceedings, 1992 joint APS/MSA meeting, Portland, OR.

Wang, C.G.; Blanchett, R.A.; Jackson, W.A.; Palmer, M.A. 1985. Differences in conidial morphology among isolates of *Sphaeropsis sapinea*. Plant Disease 69:838-841.

Wingfield, M.J.; Knox-Davies, P.S. 1980. Association of *Diplodia pinea* with a root disease of pines in South Africa. Plant Disease 64:221-223.

Reviewers' Comments

"The *Armillaria* and *Diplodia* shoot blight IPRAs seem to include a lot more personal opinion than data. This can be crucial for some issues (e.g., survival in chips) that may relate to the overall risk rating for the pest." (Oregon Department of Agriculture)

Response to Comments

Assessor judgment was used in assigning risk for pest with host-commodity at origin potential and for entry potential with the chip commodity. The reasons and the information that supports that decision for the risk assigned by the author varying from the strict application of the risk criteria are given.

ARMILLARIA ROOT ROT

Assessor—Harold H. Burdsall, Jr.

Scientific name of pest—*Armillaria hinnulea* Kile & Watl., *Armillaria luteobubalina* Kile & Watl., *Armillaria novae-zealandiae* (G. Stev.) Herink, *Armillaria pallidula* Kile & Watl.

Scientific names of host—Plantation *Pinus radiata* and other *Pinus* spp.

Distribution—All pine-growing regions of Australia are infected.

Summary of natural history and basic biology of the pest—Australia is home to at least six *Armillaria* species. Of these, four are known to occur on *Pinus* spp. *Armillaria pallidula* is known only from pine. Only *A. hinnulea* and *A. luteobubalina* have been demonstrated to be a primary pathogens in pine (Kile 1981). But *A. novae-zealandiae* may also be a mild pathogen (G. Kile, Forest and Wood Products Research and Development Corporation, 2005, pers. comm.). Other species are known as secondary pathogens, attacking stressed trees. In plantations, the Armillaria root rot attacks the very young plantings and is not a problem once the trees are well established and are more mature. Because of the approximately 30 year rotation of most pine plantations, Armillaria root rot does not become a problem on older trees (G. Kile, Forest and Wood Products Research and Development Corporation, 2005, pers. comm.). All species examined to date have the ability to cause disease in some situations, frequently in a broad range of host species. They are also adept at surviving as saprophytes in dead wood or root tissues for long periods of time (Kile 1980, 1986,

Rishbeth 1972, Shaw 1975). Under the right conditions, the fungus in the infected root—or in the case of the more saprophytic species, in infested woody debris—produces mushrooms, the source of the reproductive basidiospores. These spores are discharged and are carried by air currents to wounds in uninfected trees or to forest woody debris. In other cases, rhizomorphs may travel along infested roots and pass to another tree by root-to-root contact. *Armillaria* species are known for the production of rhizomorphs in the soil that grow out from a nutrient source and infest another substrate. There seems to be a positive correlation between the saprophytic nutritional state and the production of rhizomorphs. Most pathogenic species, such as *A. luteobubalina* and *A. hinnulea,* produce limited rhizomorphs. They are carried to a new host plant through root-to-root contact. This characteristic leads to a slower spread rate than would be attained by means of basidiospore dispersion, but it appears that the importance of the basidiospores in dissemination varies among species (Kile 1986, Smith et al. 1992). However, for the establishment of new infection foci, whether in plantations in Australia or in a foreign ecosystem, basidiospores would be very important. How these species would function in the North American ecosystem is of course unknown, but to date all Australian *Armillaria* species are known to have some pathogenic capability and a rather broad host range. Chipping logs will have little impact on whether *Armillaria* is present. Incipient infections in the sapwood will be carried in the chips into the chip piles. However, the potential for fruiting and the production of inoculum (basidiospores) on such

a substrate is low. The effect of drying, heat in the chip piles, and the presence of a myriad of competing molds will all act to reduce the viability of any *Armillaria* in the wood chips.

Specific information relating to risk elements

A. Likelihood of introduction

1. Pest with host-commodity at origin potential:

    Logs – *Moderate* (RC). Applicable rating criteria from Chapter 1: *c, e, g*.
    Chips – *Moderate* (RC). Applicable rating criteria from Chapter 1: *c, e, g*.

    Logs for export from Australia are all plantation-produced and are mostly not from initial plantings on a formerly native forest site. With each rotation, the severity of attack by *Armillaria* is reduced and is never considered more than a nuisance. The attacks are restricted to young stock, and by the time of harvest, the fungus is considered innocuous. In each rotation, the severity is lessened. Because most of the logs are produced on at least second-rotation sites and the fact there is little in the way of new *P. radiata* plantations, the fungus is not very likely to be present on exported logs. The fact that decayed butt sections are cut off during harvesting (personal observation during site visit) is comforting, but incipient attack is not obvious enough that it would be noticed in the field. This is balanced by the unknown ability of *Armillaria* to produce basidio-

spores-producing mushrooms on harvested logs.

2. Entry potential:

    Logs – *High* (VU). Applicable rating criteria from Chapter 1: *c, d*.
    Chips – *Low* (RC). Applicable rating criteria from Chapter 1: *d*.

    Armillaria species are capable of surviving well in wood for extended periods of time. Being located in the sapwood and deeper in the wood tissues of the butts of infested logs, the fungus would be protected from desiccation. However, *Armillaria* species are not known for producing basidiospore-producing mushrooms on harvested logs. It is unlikely that they would fruit in such substrates. The ability of *Armillaria* species to maintain themselves in chips is not known. However, the drying of chips in piles and the heat generated in the depths of piles may be detrimental to the fungus's survival. Decay tests performed on *A. mellea* (unpublished data) demonstrated that it was not well adapted to decaying small pieces of wood; this may indicate that chipping would select against an *Armillaria* species surviving in chips. Although it is still not certain, *Armillaria* species would probably not survive well in transported chips.

3. Colonization potential: *Low* (RC). Applicable rating criteria from Chapter 1: b, c.

    These fungi, in order to produce basidiospores, would have to develop basidiomes (mushrooms) after arrival in the US. The effectiveness

of the basidiospores in establishing the fungus would depend on that event, favorable environmental conditions (including moisture and temperature), and the presence of suitable hosts growing near ports of entry. The host range of the species in question comes into play here as well. The extent of host range for the Australian *Armillaria* species is of concern when considering importing logs. A susceptible host would need to be present for infection and colonization to occur.

4. Spread potential: *High* (RC). Applicable rating criteria from Chapter 1: *a, c, d, e, f, g*.

The spread of these fungi would depend on the presence of hosts near the ports or the location where the logs are being stored. Once spores are produced, susceptible hosts within several miles are within range of the spore dissemination. Just as in Australia, these propagules could be effective in inciting new infections.

B. Consequences of introduction

5. Economic damage potential: *High* (RC). Applicable rating criteria from Chapter 1: *a, b, c, f*.

The broad host range noted for Australian *Armillaria* species is of considerable concern. Several of the species are known to attack several species of pine as well as other conifer hosts. With regard specifically to *P. radiata*, attack of mature trees is not likely. However, whether this characteristic applies to other native U.S. conifers is unknown. If an introduced *Armillaria* species were

particularly pathogenic to some of the conifers in the western U.S., the introduction could wreak havoc in the western forests.

6. Environmental damage potential: *Low* (MC). Applicable rating criteria from Chapter 1: none.

If a species of *Armillaria* were introduced that was pathogenic to conifers in the U.S., the environmental impact would depend on the virulence and the host range of the pathogen. Such an introduction would have the potential of having a major impact by causing root rot in numerous conifer species. With effective basidiospore dispersal, new infection centers might arise rapidly, and spread could be rapid. *Armillaria* species tend to not spread rapidly, but in a new ecosystem where the host species are not adapted, it is unknown how the new pathogen would progress.

7. Social and political considerations: *Low* (MC). Applicable rating criteria from Chapter 1: none.

Perceived damage potential following successful establishment of an *Armillaria* on a conifer as a result of log importation would be low. If, however, that pathogen were particularly virulent to other hosts, especially other western conifers or a particularly rare species, the results could be much more serious.

C. Pest risk potential:

Logs – *Moderate* (Likelihood of introduction =*Low*; Consequences of introduction = *High*).

Chips – *Low* (Likelihood of introduction =*Low*; Consequences of introduction = *High*).

Selected Bibliography

Kile, G.A. 1980. Behavior of an *Armillaria* in some *Eucalyptus obliqua - Eucalyptus regnans* forests in Tasmania and its role in their decline. European Journal of Forest Pathology 10:278-296.

Kile, G.A. 1981. *Armillaria luteobubalina*: a primary cause of decline and death in mixed species eucalypt forests in central Victoria. Australian Forest Research 11:63-77.

Kile, G.A. 1986. Genotypes of *Armillaria hinnulea* in wet sclerophyll eucalypt forest in Tasmania. Transactions of the British Mycological Society 87:312-314.

Rishbeth, J. 1972 The production of rhizomorphs by *Armillaria mellea* from stumps. European Journal of Forest Pathology 2:193-205.

Shaw, C.G. III. 1975. Epidemiological insights into *Armillaria mellea* root rot in a managed ponderosa pine forest. Oregon State University, Corvallis, OR. 201 p. Ph.D dissertation.

Smith, M.L.; Bruhn, J.N.; J.B. Anderson, J.B. 1992. The fungus *Armillaria bulbosa* is among the largest and oldest living organisms. Nature 356:428-431.

Reviewers' Comments

"In the IPRA for Armillaria root rot it is claimed that 'Because of the short rotation (10-20 years) of most pine plantations, Armillaria root-rot does not become a problem on older trees or in later rotations' In NSW (and in other states) most pine plantations are actually managed for approximately 30 years (or more) before harvesting. However many pine plantations now occur on second rotation sites." (Stone)

"The *Armillaria* and *Diplodia* shoot blight IPRAs seem to include a lot more personal opinion than data. This can be crucial for some issues (e.g., survival in chips) that may relate to the overall risk rating for the pest." (Oregon Department of Agriculture)

Response to Comments

The comment is correct with regard to the length of rotation in pine plantations. The length of rotation slipped through the authors review incorrectly. The fact remains that *Armillaria* species affecting pine plantations in Australia are not problems with rotations of this length, especially when the species are not present in the native forest removed for plantation establishment. *Armillaria* is not known as a problem in pine plantations except, occasionally, in newly established plantations retrieved from the native forest. In addition the pines appears to develop resistance with age (G. Kile, Forest and Wood Products Research and Development Corporation, 2005, pers. comm.) and root rot is not found in the more mature plantations.

Much of the reason for the lack of data on Australian species of *Armillaria* as a forest pathogen is because it is not much of a problem. Even less is known regarding the survival ability of *Armillaria* species on chips, no matter what nationality. However, unpublished data (Burdsall and Banik, pers. obs.) indicates that *Armillaria mellea* grows and decays wood chips poorly in the laboratory even under ideal conditions. It would not be expected to thrive in chip piles, especially considering the treatment of such piles (e.g., the amount of heat in the piles and the stirring of the piles several

times after chipping). A study of 16 shipments of chips from Chile found no *Armillaria* cultures and, in fact, found little other than common molds, especially *Trichoderma*.

CHAPTER 4. SUMMARY AND CONCLUSIONS

BACKGROUND

Several forest industries propose to import logs and chips of *Pinus* spp. from Australia for processing in various localities in the United States. Current regulations require that unprocessed logs from temperate areas of Australia must be fumigated with methyl bromide or heat-treated to eliminate pests. Logs must be stored and handled to exclude access by pests after treatment (Title 7, CFR part 319.40-5(d), 319.40-6 (a)). The Animal and Plant Health Inspection Service (APHIS) requested that the Forest Service prepare a pest risk assessment that identifies the potential insects and pathogens of several species of *Pinus* (*P. radiata, P. elliottii* var. *elliottii, P. taeda, P. pinaster,* and *P. caribaea* var. *hondurensis*) throughout Australia, estimates the likelihood of their entry on logs or chips of the pine species into the United States, and estimates the potential for these pests to establish and spread within the United States. The pest risk assessment also evaluates the economic, environmental, social, and political consequences of any introduction. This risk assessment includes the conterminous United States and Hawaii as potential ports of entry. The assessment and conclusions are expected to be applicable to these areas.

PEST RISK ASSESSMENT

The Wood Import Pest Risk Assessment and Mitigation Evaluation Team, a group of pest specialists from various USDA Forest Service offices, compiled this pest risk assessment. The team of specialists provided technical expertise from the disciplines of forestry, entomology, plant pathology, and mycology. All team members worked on previous pest risk assessments related to log imports. Representatives from APHIS, the USDA Forest Service, and the government of Australia assisted the team. In September 2001, eight members of the team and two APHIS representatives traveled to Australia. Biosecurity Australia coordinated the site visit. The team split into smaller subgroups and visited numerous plantings and natural forests of eucalypts in various parts of the country. They also visited processing mills and ports. The team spoke with various government officials, industry representatives, and academia to discuss the risk assessment and conditions in Australia. Although the primary focus of this site visit was to evaluate the eucalypt resource in Australia, the team used the opportunity to learn about *Pinus* as well.

The team began the risk assessment process by compiling a list of organisms reported to be associated with several *Pinus* species in Australia. From this list, insects and pathogens having the greatest risk potential as pests on logs or chips were identified using risk analysis procedures recommended by APHIS (Orr et al. 1993). This pest risk assessment expanded two of the five criteria for identifying potential pests of concern (Table 7). Criterion 2a includes pests that are present in both Australia and the United States, but with restricted distribution in the United States and little chance of being internally spread within the United States because of the lack of reason for movement of contaminated material from the restricted area. Imports of such materials could well traverse and break these barriers. Criterion 4 was expanded to include 4a: native species that have reached the probable limits of their range, but may differ in their capacity for causing damage based on the genetic variation exhibited by the species. The team used a set of criteria to determine the level of risk associated with each risk element.

Eleven individual pest risk assessments (IP-RAs) were prepared for pests of the pine species, nine dealing with insect pests and two with pathogens. The organisms from these assessments are grouped in Table 10 according to the substrate they are likely to occupy (on bark, in or under bark, or inside wood). Table 10 summarizes the pest risk potential with logs as the commodity, while Table 11 summarizes the pest risk potential with chips as the commodity. The team recognizes that these organisms may not be the only ones associated with logs or chips, but they are representative of the diversity of insects and pathogens that inhabit logs. The lack of biological information on a given insect or pathogen should not be equated with low risk (USDA Forest Service 1993). However, by necessity, this pest risk assessment focuses on those insects and pathogens for which biological information is available. By developing IPRAs for known organisms that inhabit a variety of niches on logs, APHIS can subsequently identify effective mitigation measures to eliminate the recognized pests and any similar unknown organisms that inhabit the same niches.

PINUS SPP. LOGS AS COMMODITY

Some of the organisms of concern on pines would only be associated with logs as hitchhikers, most likely confined to the bark surface.

Insects and pathogens that inhabit the inner bark and wood have a higher probability of being imported with logs than do organisms on the bark, particularly in the absence of mitigation measures. Three groups of subcortical insects were identified as having a high likelihood of being associated with logs of *Pinus* spp. These include the endemic weevils (*Aesiotes* spp.), the two introduced European bark beetles (*Hylurgus ligniperda* and *Hylastes*

ater), and the exotic bark anobiid (*Ernobius mollis*). These were rated as having "Moderate," "High," and "High" pest risk potential, respectively. The weevils were rated "Moderate" because they are considered secondary insects in their natural environment and rarely cause significant damage. The exotic bark beetles and the anobiid bark beetle received a "High" rating because of their potential to possibly be more efficient vectors of the black stain root disease pathogen (*Leptographium* spp.) or other pathogenic fungi (*Ernobius mollis*).

Of the seven groups of insects and pathogens that occur in the wood, six were rated with a high risk potential. Ambrosia beetles (*Platypus subgranosus*, *Amasa truncatus*; *Xyleborus perforans*) infestations result in wood degradation caused by their galleries and by the localized staining from the associated symbiotic fungi. As controls are not currently available and costs of quarantine enforcement would be high, economic damage potential could be significant. The dampwood termite (*Porotermes adamsoni*) and the giant termite (*Mastotermes darwiniensis*) will attack untreated wood and live trees of numerous hardwood and softwood species and could cause significant damage in moist, warm climates. Drywood termites (*Neotermes insularis*; *Kalotermes rufinotum*, *K. banksiae*; *Ceratokalotermes spoliator*; *Glyptotermes tuberculatus*; *Bifiditermes condonensis*; *Cryptotermes primus*, *C. brevis*, *C. domesticus*, *C. dudleyi*, and *C. cynocephalus*) damage untreated wood in structures and result in considerable economic loss. Subterranean termites (*Schedorhinotermes intermedius intermedius*, *S. i. actuosus*, *S. i. breinli*, *S. i. seclusus*, *S. reticulatus*; *Heterotermes ferox*, *H. paradoxus*; *Coptotermes acinaciformis*, *C. frenchi*, *C. lacteus*, *C. raffrayi*; *Microcerotermes boreus*, *M. distinctus*, *M. implicadus*, *M. nervosus*, *M. turneri*; and *Nasutitermes*

Table 10—Summary of risk potentials for Australian pests of concern for unprocessed *Pinus* spp. logs (on bark, in or under bark, or in wood)[1].

Common name (*Scientific name*)	Likelihood of introduction				Consequences of introduction			Pest Risk Potential
	Host association	Entry potential	Coloni-zation potential	Spread potential	Economic damage	Environ-mental damage	Social/Political	
On bark								
Insects								
Pine loopers (*Chlenias* spp.)	M	L	H	M	M	M	L	M
Pathogens								
None								
In or under bark								
Insects								
Bark beetles (*Hylurgus ligniperda, Hylastes ater*)	H	H	H	H	M	M	M	H
Bark weevils (*Aesiotes notabilis, A. leucurus*)	H	H	H	M	M	M	L	M
Bark anobiid (*Ernobius mollis*)	H	H	H	H	M	M	L	H
Pathogens								
Diplodia shoot blight (*Sphaeopsis sapinea*)	M	H	M	M	M	M	L	M
In wood								
Insects								
Ambrosia beetles (*Platypus subgranosus, Amasa truncatus; Xyleborus perforans*)	H	H	M	H	H	M	M	H
Wood wasp (*Sirex noctilio*)	H	H	H	H	H	H	H	H
Dampwood termites (*Porotermes adamsoni*); Giant termite (*Mastotermes darwiniensis*)	H	H	H	H	H	M	H	H

Table 10—Summary of risk potentials for Australian pests of concern for unprocessed *Pinus* spp. logs (on bark, in or under bark, or in wood)[1].

Common name (*Scientific name*)	Likelihood of introduction				Consequences of introduction			Pest Risk Potential
	Host association	Entry potential	Colonization potential	Spread potential	Economic damage	Environmental damage	Social/Political	
Drywood termites (*Neotermes insularis*; *Kalotermes rufinotum, K. banksiae; Ceratokalotermes spoliator; Glyptotermes tuberculatus; Bifiditermes condonensis; Cryptotermes primus, C. brevis, C. domesticus, C. dudleyi, C. cynocephalus*)	H	H	H	H	M	L	M	H
Subterranean termites (*Schedorhinotermes intermedius intermedius, S. i. actuosus, S. i. breinli, S. i. seclusus, S. reticulatus; Heterotermes ferox, H. paradoxus; Coptotermes acinaciformis, C. frenchi, C. lacteus, C. raffrayi; Microcerotermes boreus, M. distinctus, M. implicadus, M. nervosus, M. turneri; Nasutitermes exitiosis*)	H	H	H	H	H	M	M	H
Pathogens								
Armillaria root rot (*Armillaria hinnulea, A. luteobubalina, A. novae-zealandiae, A. pallidula*)	M	H	L	H	H	L	L	M

[1]H=high rating; M=moderate rating; L=low rating

Table 11—Summary of risk potentials for Australian pests of concern for unprocessed *Pinus* spp. chips[1].

Common name (*Scientific name*)	Likelihood of introduction				Consequences of introduction			Pest Risk Potential
	Host associ-ation	Entry poten-tial	Coloni-zation potential	Spread potential	Economic damage	Environ-mental damage	Social/ Political	
On bark								
Insects								
Pine Loopers (*Chlenias* spp.)	L	L	H	M	M	M	L	L
Pathogens								
None								
In or under bark								
Insects								
Bark beetles (*Hylurgus ligniperda, Hylastes ater*)	L	M	H	H	M	M	M	M
Bark weevils (*Aesiotes notabilis, A. leucurus*)	L	L	H	M	M	M	L	L
Bark anobiid (*Ernobius mollis*)	L	L	H	H	M	M	L	L
Pathogens								
Diplodia shoot blight (*Sphaeopsis sapinea*)	L	L	M	M	M	M	L	L
In wood								
Insects								
Ambrosia beetles (*Platypus subgranosus, Amasa truncatus, Xyleborus perforans*)	M	M	M	H	H	M	M	M
Wood wasp (*Sirex noctilio*)	L	L	H	H	H	H	H	L
Dampwood termite (*Porotermes adamsoni*)	L	L	H	H	H	M	H	L
Giant termite (*Mastotermes darwiniensis*)	L	L	H	H	H	M	H	L

Table 11—Summary of risk potentials for Australian pests of concern for unprocessed *Pinus* spp. chips[1].

| Common name (*Scientific name*) | Likelihood of introduction | | | | Consequences of introduction | | | Pest Risk Potential |
	Host associ-ation	Entry poten-tial	Coloni-zation potential	Spread potential	Economic damage	Environ-mental damage	Social/ Political	
Drywood termites (*Neotermes insularis; Kalotermes rufinotum, K. banksiae; Ceratokalotermes spoliator; Glyptotermes tuberculatus; Bifiditermes condonensis; Cryptotermes primus, C. brevis, C. domesticus, C. dudleyi, C. cynocephalus*)	L	L	H	H	M	L	M	L
Subterranean termites (*Schedorhinotermes intermedius intermedius, S. i. actuosus, S. i. breinli, S. i. seclusus, S. reticulatus; Heterotermes ferox, H. paradoxus; Coptotermes acinaciformis, C. frenchi, C. lacteus, C. raffrayi; Microcerotermes boreus, M. distinctus, M. implicadus, M. nervosus, M. turneri; Nasutitermes exitiosis*)	L	L	H	H	H	M	M	L
Pathogens								
Armillaria root rot (*Armillaria hinnulea, A. luteobubalina, A. novae-zealandiae, A. pallidula*)	M	L	L	H	H	L	L	H

[1]H=high rating; M=moderate rating; L=low rating

exitiosis) attack untreated wood and some attack live trees. They could compete with native termites that degrade and decompose wood in use, and could pose a significant hazard to street trees. The introduced wood wasp (*Sirex noctilio*) has demonstrated its capacity for being a significant mortality agent in stressed pines in many countries and merits a high rating of pest risk potential on that basis.

The deep-wood Armillaria root rot fungi (*Armillaria hinnulea*, *A. luteobubalina*, *A. novae-zealandiae,* and *A. pallidula*) were rated as moderate risk potential rather than high because of the low likelihood of these fungi producing badidomes and basidiospores needed for colonization upon arrival in the United States.

In assessing the risk of potential pests, the fact that insects and microorganisms invade logs in a predictable temporal sequence, dictated by the condition of the host, is important. At the time of felling, logs will contain any pathogens and borers present in the bole of the living tree. Certain life stages of defoliating insects may be attached to the bark. Within the first several weeks after felling, beetles and borers may colonize logs. Also, certain woodborers may deposit eggs on the bark of logs shortly after harvest. Whether bark- and wood-boring insects will be common on export logs will depend in part on how rapidly the logs are removed from harvest sites and loaded onto ships, trains, or trucks for transport to the United States.

PINUS SPP. CHIPS AS COMMODITY

When chips rather than logs are considered as the commodity, the risk potential changes for several of the groups of organisms (Table 11). Ratings for the insects that occur in the wood change considerably. The high risk potential for ambrosia beetles dropped from high to moderate. The high risk potential for the Sirex wood wasp, dampwood termite, the giant termite, the drywood termites, and the subterranean termites dropped from high to low. For host material infested with those insects before chipping, it was thought unlikely that any life stage that would pass successfully through the chipping process could subsequently survive in chips due to altered moisture and temperature. The two groups retaining a moderate rating (ambrosia beetles and exotic bark beetles) do so on the remote likelihood that small adults would survive the chipping process in host material previously infested prior to chipping.

The changes in risk potentials for the two commodities, logs and chips, are compared directly in Table 12.

We recognize that other potential pathways exist for the introduction of forest pests. Though deserving of examination, these pathways may be difficult if not impossible to predict and are not a focus of this assessment.

FACTORS INFLUENCING RISK POTENTIAL

During site visits we were informed about and observed differences in harvesting and processing practices among regions of Australia. These differences, such as debarking efficiency, can influence the risk potential for certain pests, especially hitchhikers and those that invade the inner bark. In addition to harvesting practices, some differences were noted among regions of Australia in the occurrence and extent of certain pest organisms. These differences are noted in the individual pest risk assessments. They may influence the risk potential for certain organisms from specific regions.

Table 12—Summary of risk potentials for Australian pests of concern, *Pinus* spp. logs versus chips as the commodity[1].

Organisms	Logs	Chips
On bark		
Pine loopers	M	L
In or under bark		
Bark weevils (*Hylurgus ligniperda, Hylastes ater*)	H	M
Diplodia shoot blight	M	L
In wood		
Ambrosia beetles	H	M
Sirex noctilio	H	L
Dampwood termites	H	L
Giant termite	H	L
Drywood termites	H	L
Subterranean termites	H	L
Armillaria root rot	M	L

[1]H=high rating; M=moderate rating; L=low rating

EFFECTS OF CHIPPING ON INSECTS AND PATHOGENS

Other practices, such as chip production, can also influence the likelihood of pest presence and transport. The risk rating of potential pest species examined the difference between whole log importation and chip importation. Clearly, debarking and reducing logs to chips will seriously impact the survival and hence the risk of importation of certain pests. Some pests, primarily insects, will be adversely affected by chipping either by the actual destruction of living organisms or by the disruption of host material as it affects completion of life stages. Thus, of the insects for which IPRAs were done, all except the ambrosia beetles and smaller bark beetles are at moderate likelihood of surviving chipping and transport, thereby retaining a "Moderate" pest risk potential. The extent of insect population reduction due to chipping would vary from virtual elimination to various levels of reduction, depending on insect size and life stage, operating characteristics of the chipping machinery, and other factors.

Other organisms, such as fungi, may not be affected by chipping or could be positively or negatively affected. The production of chips will result in considerably more surface area on which fructifications could develop. It would also make it impossible to visually inspect for certain defects, such as cankers and decay. The smaller the size of the wood chips, the quicker they would dry out, and the lower the risk of potential pests survival. Smaller size chips would probably not provide an adequate food base to permit fruiting of decay fungi, but these fungi could survive as mycelia or rhizomorphs. Also, large piles of chips will generate heat internally and possibly have large areas under anaerobic conditions that may be damaging to fungal pathogens,

either directly or through the encouragement of thermophilic fungi that may be antagonistic to the pathogens. Internal temperatures of hardwood chip piles have been reported to reach 49 to 82°C after 5 to 7 days (Fuller 1985), temperatures sufficiently high to inhibit or kill most fungal pathogens. Heat treatments ranging from 65.6°C for 75 minutes to 100°C for 5 minutes generally have been regarded as the minimal times and internal wood temperatures required for wood sterilization. However, some fungi isolated from woodchip piles have been found to survive exposure to temperatures of 65°C or greater for times ranging from 8 to 72 hours (Zabel and Morrell 1992), while chips on the surface of undisturbed chip piles will be unaffected by internal heating. While chipping, piling, storage, and transporting pines may alter the risk of pest importation, there is little or no information on the magnitude of risk reduction. Other risks, such as insect hitchhikers on transport vehicles, would remain unchanged.

The temperature, moisture, and air content in wood chip piles vary with the pile volume and over time. Although the piles may rest undisturbed for extended periods, they also undergo repeated mixing during transportation, storage, and distribution. These dynamics may affect insect and pathogen survival, reproduction, and population levels, as well as community composition. Heat generated during the decomposition process favors thermotolerant and thermophilic organisms over mesophilic organisms. Dwinell (1986) found that in piled southern pine chips, the pinewood nematode [*Bursaphelenchus xylophilus* Steiner and Buhrere) Nickel] primarily inhabits fresh chips and chips located in the outer shell of the pile due to heat generated during the decomposition process, whereas chips in the interior of the pile do not harbor the nematode when oxidative processes cause

spontaneous heating to 60°C (140°F). Dwinell (1987) and Leesch et al. (1989) investigated the population dynamics of the pinewood nematode in southern pine chips stored in the hold of ships during transport from Georgia to Sweden. Chips in the bottom of holds averaged temperatures of 35°C (95°F) and contained high levels of the pinewood nematode. Few pinewood nematodes were found in the middle of holds, where temperatures averaged 48°C (118°F). Dwinell concluded that the bottom of the holds served as an incubator for the nematode during the 17- to 19-day voyages. In laboratory studies, population densities of the pinewood nematode declined rapidly at temperatures above 45°C (113°F), and the nematode was not recovered after 1 and 3 days at 50 and 48°C (122 and 118°F), respectively (Dwinell 1990).

In a study of Monterey pine infected with the pitch canker pathogen *Fusarium circinatum* Nirenber and O'Donnell, chipping branches reduced the emergence of twig beetles (*Pityophthorus* spp. and associates) by about 95 percent, compared with emergence from intact branches (McNee et al. 2002). The frequency of pathogen isolation from branch chips was highly variable and increased with increasing severity of disease symptoms. Pathogen isolation frequencies from one-year-old chips were lower than in fresh chips, but the reduction was not significant in chips with low initial isolation frequencies.

Micales and Burdsall (2002) analyzed samples from 16 shipments of unprocessed *Pinus radiata* chips exported from Chile to Bellingham, Washington. Six fungal genera (*Geotrichum*, *Gloeocladium*, *Paecilomyces*, *Penicillium*, *Phanerochaete*, and *Trichoderma*) were consistently recovered and represented nearly 90 percent of the isolates. Species of *Trichoderma* accounted for nearly half of the

total species isolated. *Graphium*, a genus of potential bluestain or vascular wilt pathogens, was recovered from only 0.32 percent of the specimens. They concluded that species of *Trichoderma* appear to competitively inhibit other fungi in woodchip shipments.

CONCLUSIONS

There are numerous potential pest organisms found on *Pinus* spp. in Australia that have a high likelihood of being inadvertently introduced into the United States on unprocessed logs or chips. Some of these organisms are attracted to recently harvested logs while others are affiliated with logs in a peripheral fashion, but nonetheless pose serious threats to pines or other hosts in the United States. Thus, the potential mechanisms of log and chip infestation by nonindigenous pests are complex.

The array of potential hosts in the U.S. is not fully known. Until more specific information is available, caution seems prudent.

For those organisms of concern that are associated with the species of *Pinus* considered in this PRA, specific phytosanitary measures may be required to ensure the quarantine safety of proposed importations. Detailed examination and selection of appropriate phytosanitary measures to mitigate pest risk is the responsibility of APHIS as part of the pest risk management phase (Orr et al. 1993) and is beyond the scope of this assessment.

CHAPTER 5. BIBLIOGRAPHY

This is an inclusive bibliography meant to provide the reader with an extensive list of possible sources of information on the subject of pests of *Pinus* in the United States and Australia.

ABARE. 2002. Australian Forest and Wood Product Statistics, September and December quarters 2001. Canberra, ACT: Australian Bureau of Agricultural and Resource Economics. 67 p.

ABARE. 2005. Australian Forest and Wood Product Statistics, September and December quarters 2004. Canberra, ACT: Australian Bureau of Agricultural and Resource Economics. 60 p.

Adams, A.J.S. 1950. Control of the pine bark beetle (*Hylastes ater*) at Mt. Burr, South Australia. Australian Forestry 14:111-112.

Aguilar, A. 1985. Descripción e identificación de organismos asociados al azulado de la madera aserrada en pino isigne (*Pinus radiata* D. Don). Valdivia: Ingeniería Forestal Universidad Ausatral de Chile. Tesis. 67 p.

Anonymous. 2005. Australian Insect Common Names. CSIRO. *http://www.ento. csiro.au/aicn/index.htm.*

Australian Academy of Technological Sciences and Engineering. 1988. Technology in Australia 1788-1988. Melbourne, VIC: Australian Science and Technology Heritage Centre, The University of Melbourne. 958 p.

Bain, J. 1977. *Hylurgus ligniperda* (Fab.). Forest and timber insects in New Zealand No. 18. Rotorua: Forest Research Institute, New Zealand Forest Service. 6 p.

Bain, J.; Jenkin, M.J. 1983. *Kalotermes banksiae*, *Glyptotermes brevicornis*, and other termites (Isoptera) in New Zealand. New Zealand Entomologist 7:365-371.

Baker, W.L. 1972. Eastern forest insects. Miscellaneous Publication 1175. Washington, D.C; U.S. Department of Agriculture, Forest Service. 642. p.

Bedding, R.A. 1972. Biology *of Deladenus siricidicola* (Neotylenchidae) an entomophagous- mycetophagous nematode parasitic in siricid woodwasps. Nematologica 18:482-493.

Bedding, R.A.; Akhurst, R.J. 1974. Use of the nematode *Deladenus siricidicola* in the biological control of *Sirex noctilio* in Australia. Journal of the Australian Entomological Society 13:129-135.

Bedding, R.A.; Akhurst, R.J. 1978. Geographical distribution and host preferences of *Deladenus* species (Nematoda: Neotylenchidae) parasitic in siricid woodwasps and associated hymenopterous parasitoids. Nematologica 24:286-294.

Bedding, R.A.; Iede, E.T. 2005. Application of *Beddingia siricidicola* for sirex woodwasp control. Pp. 385-399. In: Grewal, P.S.; Ehlers, R.-U.; Shapiro-Ilan, D.I., eds. Nematodes as biological control agents. CABI Publishing.

Bess, H.A. 1970. Termites of Hawaii and the oceanic islands. Pp. 449-476. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Billings, R.F.; Holsten, E.H. 1969. Progreso realizado en la investigación de insectos forestales de pino insigne (Dic. 1967 hasta Agosto 1969). Santiago: División Forestal, Servicio Agrícola y Ganadero, Universidad de Chile, Cuerpo de Paz. 49 p. (Mimeographed report.)

Billings, R.F.; Holsten, E.H.; Eglitis, A. 1972. Insects associated with *Pinus radiata* D. Don in Chile. Turrialba (Costa Rica) 22(1):105-108.

Blodgett, J.T.; Stanosz, G.R. 1997. *Sphaeropsis sapinea* morphotypes differ in aggressiveness, but both infect nonwounded red or jack pines. Plant Disease 81:143-147.

Boomsma, C.P.; Adams, A.J.S. 1943. Pine bark beetle (*Hylastes ater*) at Mount Burr, South Australia. Australian Forestry 7:33-37.

Britton, D.R.; New, T.R. 2004. Exotic pine plantations and indigenous Lepidoptera in Australia. Journal of Insect Conservation 8:263-274.

Brimblecombe, A.R. 1945. The biology, economic importance and control of the pine bark weevil *Aesiotes notabilis* Pasc. Queensland Journal of Agricultural Science 2:1-88 (Reprinted as Queensland Forest Service Bulletin No. 14. 88 p.)

Brimblecombe, A.R. 1953. An annotated list of the Scolytidae occurring in Australia. Queensland Journal of Agricultural Science 10:167-205 (Reprinted as Queensland Department of Agriculture and Stock Bulletin No.71. 39 p.)

Brimblecombe, A.R. 1957. The pine bark anobiid. Queensland Agricultural Journal 83:637-639.

Brockerhoff, E.G.; Bain, J. 2000. Biosecurity implications of exotic beetles attacking trees and shrubs in New Zealand. New Zealand Plant Protection 53:321-327.

Brown, W.V.; Watson, J.A.L.; Lacey, M.J. 1994. The cuticular hydrocarbons of workers of three Australian *Coptotermes* species, *C. michaelseni*, *C. brunneus* and *C. dreghorni* (Isoptera: Rhinotermitidae). Sociobiology 23:277-291.

Brown, W.V.; Watson, J.A.L.; Lacey, M.J. 1996. A chemosystematic survey using cuticular hydrocarbons of some species of the Australian harvester termite genus *Drepanotermes* (Isoptera: Termitidae). Sociobiology 27:199-221.

Burgess, T.; Wingfield, B.W.; Wingfield, M.J. 2001. Comparison of genotypic diversity in natural and introduced populations of *Sphaeropsis sapinea* isolates from *Pinus radiata*. Mycological Research 105:1331-1339.

Burgess, T.; Wingfield, M.J.; Wingfield, B.W. 2001. Simple sequence repeat markers distinguish among morphotypes of *Sphaeropsis sapinea*. Applied and Environmental Microbiology 67:354-362.

Carnegie, A.J.; et al. 2005. Predicting the potential distribution of *Sirex noctilio* (Hymenoptera: Siricidae), a significant exotic pest of *Pinus* plantations. Annals of Forest Science 63:1-9.

Casimir, J.M. 1958. *Ernobius mollis* Linn., an introduced bark beetle. Forestry Commission of New South Wales, Division of Wood Technology, Technical Notes 11:24-27.

Chou, C.K.S. 1976a. A shoot dieback in *Pinus radiata* caused by *Diplodia pinea*. I: Symptoms, disease development, and isolation of pathogen. New Zealand Journal of Forestry Science 6:72-79.

Chou, C.K.S. 1976b. A shoot dieback in *Pinus radiata* caused by *Diplodia pinea*. II: Inoculation studies. New Zealand Journal of Forestry Science 6:409-420.

Chou, C.K.S.; Mackenzie, M. 1988. Effect of pruning intensity and season on *Dilodia pinea* infection of *Pinus radiata* stems through pruning wounds. New Zealand Journal of Forestry Science 12:425-437.

Ciesla, W.M. 1988. Pine bark beetles: a new pest management challenge for Chilean forests. Journal of Forestry 86(12):27-31.

Cogollor, G. 1991. Estudio de los antecedentes biologicos para el control de *Hylurgus ligniperda* e *Hylastes ater* (Coleoptera: Scolytidae) en plantaciones de *Pinus radiata* D. Don., propiedad de Forestal Cholguan. Chile: Bosque de Ingenieria, Ltda., informe final. 69 p.

Collins, M.S. 1969. Water relations in termites. Pp. 433-458. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Coutts, M.P. 1969a. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata.* I: Effects of the symbiotic fungus *Amylostereum* spp. (Thelophoraceae). Australian Journal of Biological Science 22:915-924.

Coutts, M.P. 1969b. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata*. II: Effects of *S. noctilio* mucus. Australian Journal of Biological Science 22:1153-1161.

Coutts, M.P. 1969c. The formation of polyphenols in small blocks of *Pinus radiata* sapwood with and without the fungal symbiont of *Sirex*. Australian Forestry Research 4(l):29-34.

Craighead, F.C. 1949. Insect enemies of eastern forests. Miscellaneous Publication 657. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 679 p.

De Wet, J.; Wingfield, M.J.; Coutinho, T.A.; Wingfield, W.D. 2000. Characterization of *Sphaeropsis sapinea* isolates from South Africa, Mexico and Indonesia. Plant Disease 84:151-156.

Duraflora, E.T. 1993. Susceptibilidade de toras de pinheiros tropicais ao ataque da vespa-da-madeira *Sirex noctilio* (Hymenoptera: Siricidae). Pp. 97-109. In: Conferencia Regional da Vespa da Madeira, *Sirex noctilio*, na America do Sul. EMBRAPA, Colombo, PR, Brasil.

Dwinell, L.D. 1986. Ecology of pinewood nematode in southern pine chip piles. USDA Forest Service, Southeastern Forest Experiment Station, Research Paper SE-258. Asheville, N.C. 14 p.

Dwinell, L.D. 1987. Pine wood nematode in southern pine chips exported from Georgia. Pp. 50-57. In: Wingfield, M.J., ed. Pathogenicity of the Pine Wood Nematode. St. Paul, MN: American Phytopathological Society Press.

Dwinell, L.D. 1990. Thermal death point of *Bursaphelenchus xylophilus* in southern pine chips. Nematologica 36:346.

Ebeling, W. 1975. Urban entomology. University of California, Division of Agricultural Sciences. 695 p.

Edwards, R.; Mill, A.E. 1986. Termites in buildings. Their biology and control. East Grinstead: Rentokil Limited. 261 p.

Eldridge, R.H. 1983. Introduced pine bark beetles in New South Wales. Forestry Commission of New South Wales, Forest Protection Series No. 5:1-3.

Elliott, H.J.; Bashford, R. 1984. Incidence and effects of the dampwood termite, *Porotermes adamsoni*, in two Tasmanian east coast eucalypt forests. Australian Forestry 47:11-15.

Elliott, H.J.; Ohmart, C.P.; Wylie, F.R. 1998. Insect pests of Australian forests: Ecology and management. Inkata Press, Melbourne, Sydney, Singapore. 214 p.

Flynn, R.; Shield, E. 1999. Eucalyptus: progress in higher value utilization, a global review. Tacoma, WA and Annerley, Queensland, Australia: Robert Flynn & Associates and Economic Forestry Associates. 212 p.

French, J.R.J. 1986. Termites and their economic importance in Australia. Pp. 103-129. In: Vinson, S.B., ed. Economic impact and control of social insects. Praeger: New York.

Froggatt, W.W. 1923. Forest insects of Australia. (Government Printer: Sydney). 171 p.

Froggatt, W.W. 1925. Forest insects. No. (12) 13: The island pinhole borer (*Xyleborus perforans* Wolliston), Australian Forestry Journal 8:232-234.

Froggatt, W.W. 1926a. Forest insects. No. 21: The ridge-tailed borer. *Amasa truncata,* Erichson. Australian Forestry Journal 9:144-146.

Froggatt, W.W. 1926b. Forest insects. No. 25: Shot hole borers (ambrosia beetles) belonging to the genus *Platypus*. Australian Forestry Journal 9:256-260.

Fuller, W.S. 1985. Chip pile storage—a review of practices to avoid deterioration and economic losses. Tappi 68:49–52.

Gardiner, P. 1953. The biology and morphology of *Ernobius mollis* L. (Coleoptera: Anobiidae). Trans. Roy. Entom. Soc. Lond. 104:1-24.

Gay, F.J. 1969. Species introduced by man. Pp. 459-494. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Gay, F.J.; Calaby, J.H. 1970. Termites of the Australian Region. Pp. 393-448. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Gibson, I.A.S. 1979. Diseases of forest trees widely planted as exotics in the tropics and Southern hemisphere. II: The genus *Pinus*. Oxford, England: Commonwealth Mycological Institute, Kew Surrey, and Commonwealth Forestry Institute, University of Oxford. 135 p.

Greaves, T. Termites as forest pests. Australian Forestry 23:114-120.

Greaves, T.; McInnes, R.S.; Dowse, J.E. 1965. Timber losses caused by termites, decay, and fire in an alpine forest in New South Wales. Australian Forestry 29:161-174.

Haack, R.A. 2001. Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985-2000. Integrated Pest Management Reviews 6:253-282.

Hadlington, P. 1951. Bark beetles. Forestry Commission of New South Wales, Division of Wood Technology, Technical Notes 5:26-30.

Harris, J.A.; Campbell, K.G.; Wright, G.M. 1976. Ecological studies on the horizontal borer *Austroplatypus incompertus* (Schedl) (Coleoptera: Platypodidae). Journal of the Entomological Society of Australia (N.S.W.) 9:11-21.

Haugen, D.A.; Underdown, M.G. 1990. *Sirex noctilio* control program in response to the 1987 Green Triangle outbreak. Australian Forestry 53:33-40.

Haugen, D.A.; Bedding, R.A.; Underdown, M.G.; Neumann, F.G. 1990. National strategy for control of *Sirex noctilio* in Australia. Australian Forest Grower 13(2): special liftout section No. 13. 8 p.

Hausner, G.; Hopkin, A.A.; Davis, C.N.; Reid, J. 1999. Variation in culture and rDNA among isolates of *Sphaeropsis sapinea* from Ontario and Manitoba. Canadian Journal of Plant Pathology 21:256-264.

Haverty, M.I.; Woodrow, R.J.; Nelson, L.J.; Grace, J.K. 2000. Cuticular hydrocarbons of termites of the Hawaiian Islands. Journal of Chemical Ecology 26:1167-1191.

Haverty, M.I.; Woodrow, R.J.; Nelson, L.J.; Grace, J. K. 2005. Identification of termite species by the hydrocarbons in their feces. Journal of Chemical Ecology 31:2119-2151.

Heather, W.A.; Pratt, B.H. 1975. Association of *Phytophthora drechsleri* Tucker with death of *Pinus radiata* D. Don in southern New South Wales. Australian Journal of Botany 23:285-288.

Hildebrand, D.M. 2001. *Ernobius mollis*. Pest Reports – EXFOR Database. *http://spfnic.fs.fed.us/exfor/data/pestreports.cfm.*

Hogan, T.W. 1948. Pin-hole borers of fire-killed mountain ash. The biology of the pin-hole borer – *Platypus subgranosus* S. Journal of Agriculture, Victoria 46:373-380.

Howard, J.L. 2001. U.S. timber production, trade, consumption, and price statistics 1965-1999. Research Paper FPL-RP-595, Madison, WI: U.S. Department of Agriculture Forest Service, Forest Products Laboratory. 90 p.

Howard, J.L. 2002. U.S. forest products annual market review and prospects, 2000-2003. Research Note FPL-RN-287, Madison, WI: U.S. Department of Agriculture Forest Service, Forest Products Laboratory. 5 p.

Iede, E.T.; Penteado, S.R.C.; Schaitza, E.G., 1998. *Sirex noctilio* problem in Brazil: detection, evaluation, and control. Pp. 45-52. In: Proceeding of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA Forest Service, FHTET 98-13.

Johnson, T.G. 2001. United States timber industry: An assessment of timber product output and use. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 145 p.

Johnson, T.G.; Steppleton, C.D. 2005. Southern pulpwood production, 2003. Resour. Bull. SRS-101. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 38 p.

Kile, G.A. 1980. Behavior of an *Armillaria* in some *Eucalyptus obliqua - Eucalyptus regnans* forests in Tasmania and its role in their decline. European Journal of Forest Pathology 10:278-296.

Kile, G.A. 1981. *Armillaria luteobubalina*: a primary cause of decline and death in mixed species eucalypt forests in central Victoria. Australian Forest Research 11:63-77.

Kile, G.A. 1986. Genotypes of *Armillaria hinnulea* in wet sclerophyll eucalypt forest in Tasmania. Transactions of the British Mycological Society 87:312 – 314.

Kirk, A.A. 1974. Siricid woodwasps and their associated parasitoids in the southeastern United States (Hymenoptera: Siricidae). Journal of the Georgia Entomological Society 9:139-144.

Kirk, A.A. 1975. Siricid woodwasps and their associated parasitoids in the southwestern United States (Hymenoptera: Siricidae). Pan-Pacific Entomologist 51:57-61.

Kliejunas, John T.; Tkacz, Borys M.; Burdsall, Harold H., Jr.; DeNitto, Gregg A.; Eglitis, Andris; Haugen, Dennis A.; Wallner, William E. 2001. Pest risk assessment of the importation into the United States of unprocessed *Eucalyptus* logs and chips from South America. General Technical Report FPL-GTR-124. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 134 p.

Kliejunas, John T.; Burdsall, Harold H., Jr.; DeNitto, Gregg A.; Eglitis, Andris; Haugen, Dennis A.; Haverty, Michael I.; Micales, Jessie A.; Tkacz, Borys M.; Powell, Mark R. 2003. Pest risk assessment of the importation into the United States of unprocessed logs and chips of eighteen eucalypt species from Australia. General Technical Report FPL-GTR-137. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 206 p.

Krombein, K.V.; et al. 1979. Catalogue of Hymenoptera in America north of Mexico, Vol. 1, (Symphyta and Apocrita). Washington, D.C., Smithsonian Institution Press.

Leesch, J.G.; Davis, R.; Simonaitis, R.A.; Dwinell, L.D. 1989. In-transit shipboard fumigation of pine woodchips to control *Bursaphelenchus xylophilus*. EPPO Bulletin 19:173-181.

Light, S.F. 1927. A new and more exact method of expressing important specific characters of termites. Univ. California Publ. Entomol. 4:75-88.

Love, G.; Yainshet, A; Grist, P. 1999. Forest Products: Long Term Consumption Projections for Australia. Canberra, ACT: ABARE Research Report 99.5. 90 p.

MacKenzie, M. 1992. Potential forest exports and pests from New Zealand. In: Log imports and introduced forest pests into the Pacific Northwest. Symposium Proceedings. Oregon State University, Corvallis; 21-23 April, 1992. 7 p.

McNee, W.R.; Wood, D.L., Storer, A.J.; Gordon, T.R. 2002. Incidence of the pitch canker pathogen and associated insects in intact and chipped Monterey pine branches. The Canadian Entomologist 134:47-58.

Madden, J.L. 1988. *Sirex* in Australia. Pp. 407-429. In: Berryman, A.A., ed. Dynamics of forest insect populations. New York: Plenum.

Madden, J.L.; Bashford, R. 1977a. The life history and behaviour of *Chlenias* sp. a geometrid defoliator of radiata pine in Tasmania. Journal of Australian Entomological Society 16:371-378.

Madden, J.L.; Bashford, R. 1977b. Population biology of *Chlenias* sp. a geometrid defoliator of *Pinus radiata* in Tasmania. Journal of Australian Entomological Society 16:379-388.

Maderni, J. F. P. 1998. *Sirex noctilio* F.: present status in Uruguay. Pp.81-82. In: Proceeding of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA Forest Service, FHTET 98-13.

Mampe, C.D. 1990. Termites. Pp. 201-262. In: Mallis, A., ed. Handbook of pest control. The behavior, life history and control of household pests. Cleveland, OH, Franzak and Foster, Co.

Medvedev, G.S. 1993. Keys to the Insects of the European Part of the USSR. Vol. 3: Hymenoptera, Part 4: Symphyta. Amerind. Pub. Co., New Delhi.

Micales, J.A.; Burdsall, H.H. Jr. 2002. Isolation of fungi from unprocessed *Pinus radiata* chips exported from Chile to the United States (abstract). Phytopathology 92(6):556.

Miller, E.M. 1969. Caste differentiation in the lower termites. Pp. 283-310. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume I. New York, NY: Academic Press.

Miller, L.R. 1997. Systematics of the Australian Nasutitermitinae with reference to evolution within the Termitidae (Isoptera). Ph.D. Thesis, Australian National University, Canberra, ACT, Australia. 170 p.

Milligan, R.H. 1977. *Ernobius mollis* Linnaeus (Coleoptera: Anobiidae), pine bark anobiid. Forest and Timber Insects in New Zealand 17. Rotorua: Forest Research Institute, New Zealand Forest Service. 7 p.

Milligan, R.H. 1978. *Hylastes ater* (Paykull), black pine bark beetle. Forest and timber insects in New Zealand No. 29. Rotorua: Forest Research Institute, New Zealand Forest Service. 7 p.

Minko, G. 1965. Termites in living *Pinus radiata*. Forests Commission Victoria, Forestry Technical Papers 15:1-3.

Morgan, F.D.; Stewart, N.C. 1966. The biology and behaviour of the woodwasp *Sirex noctilio* F. in New Zealand. Transactions of the Royal Society of New Zealand (Zoology) 7:195-204.

National Forest Inventory. 2005. National Plantation Inventory 2005. Canberra, ACT: Australian Bureau of Rural Sciences. 8 p.

Neilson, D.; Flynn, B. 1999. International woodchip and pulplog trade review: 1999 ed. Rotorua, New Zealand: DANA Limited.

Neumann, F.G. 1979. Beetle communities in eucalypt and pine forests in northeastern Victoria. Australian Forestry Research 9:277-293.

Neumann, F.G. 1987. Introduced bark beetles on exotic trees in Australia with special reference to infestations of *Ips grandicollis* in pine plantations. Australian Forestry 50(3):166-178.

Neumann, F.G.; Harris, J.A. 1974. Pinhole borers in green timber. Australian Forestry 37:132-141.

Neumann, F.G.; Marks, G.C. 1976. A synopsis of important pests and diseases in Australian forests and nurseries. Australian Forestry 39:83-102.

Neumann, F.G.; Marks, G.C. 1990. Status and management of insect pests and diseases in Victorian softwood plantations. Australian Forestry 53(2):131-144.

Neumann, F.G.; Minko, G. 1981. The *Sirex* woodwasp in Australian radiata pine plantations. Australian Forestry 44:46-63.

Nobles, M.K. 1965. Identification of cultures of wood-inhabiting Hymenomycetes. Canadian Journal of Botany 43:1097-1139.

Oliveira, E.B.; Penteado, S.R.C.; Iede, E.T. 1998. Forest management for the prevention and control of *Sirex noctilio* in *Pinus radiata*. Pp.67-75. In: Proceeding of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA Forest Service, FHTET 98-13.

Orr, R.L.; Cohen, S.D.; Griffin, R.L. 1993. Generic non-indigenous pest risk assessment process (for estimating pest risk associated with the introduction of non-indigenous organisms). U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 40 p.

Palmer, M.A.; Stewart, E.L.; Wingfield, M.J. 1987. Variation among isolates of *Sphaeropsis sapinea* in the north central United States. Phytopathology 77:944-948.

Paton, R.; Creffield, J.W. 1987. The tolerance of some timber insect pests to atmospheres of carbon dioxide and carbon dioxide in air. International Pest Control 29:10-12.

Peters, B.C.; King, J.; Wylie, F.R. 1996. Pests of timber in Queensland. Queensland, Australia: Queensland Forestry Research Institute, Department of Primary Industries, Queensland. 175 p.

Peterson, G.W. 1981. Control of diplodia and dothistroma blight of pines in the urban environment. Journal of Arboriculture 7:1-7.

Peterson, G.W. 1982. Diplodia blight of pines. Forest Insect and Disease Leaflet 161. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 7 p.

Rishbeth, J. 1972 The production of rhizomorphs by *Armillaria mellea* from stumps. European Journal of Forest Pathology 2:193-205.

Rust, M.K.; Reierson, D.A.; Paine, E.O.; Kellum, K.; Haagsma, K. 1998. Ravenous Formosan subterranean termite persists in California. California Agriculture 52:34-37.

Scheffrahn, R.H.; Cabrera, B.J.; Kern, W.H., Jr.; Su, N.-Y. 2002. *Nasutitermes costalis* (Isoptera: Termitidae) in Florida: first record of a non-endemic establishment by a higher termite. Florida Entomologist 85:273-275.

Schroeder, L.M. 1990. Occurrence of insects in coniferous roundwood imported to Sweden from France and Chile. EPPO (European and Mediterranean Plant Protection Organization) Bulletin 20:591-596.

Setter, R.R.; Myles, T.G. 2005. First record of *Microcerotermes* (Isoptera: Amitermitinae: Termitidae) from the continental United States, with observations on its unique ecology. American Entomologist 51:96-103.

Seybold, S.J. 2001. *Ernobius mollis* (L.) (Coleoptera: Scolytidae): an exotic beetle colonizes Monterey pine, *Pinus radiata* D. Don, in northern California. Pan-Pacific Entomologist 77:51-53.

Seybold, S.J.; Tupy, J.L. 1993. *Ernobius mollis* (L.) (Coleoptera: Scolytidae) established in California. Pan-Pacific Entomologist 69:36-40.

Shaw, C.G. III. 1975. Epidemiological insights into *Armillaria mellea* root rot in a managed ponderosa pine forest. Corvallis, OR. Oregon State University. 201 p. Ph.D dissertation.

Sinclair, W.A.; Lyon, H.H.; Johnson W.T. 1987. Diseases of trees and shrubs. Ithaca, NY: Cornell University Press. 574 p.

Smith, D.R.; Stanosz, G.R. 1995. Confirmation of two distinct populations of *Sphaeropsis sapinea* in the north central United States using RAPDs. Phytopathology 85:699-704.

Smith, H.; Wingfield, M.J.; Crous, P.W.; Coutinho, T.A. 1996. *Sphaeropsis sapinea* and *Botryosphaeria dothidea* endophytic in *Pinus* spp. and *Eucalyptus* spp. in South Africa. South African Journal of Botany 62:86-88.

Smith, M.L.; Bruhn, J.N.; J.B. Anderson, J.B. 1992. The fungus *Armillaria bulbosa* is among the largest and oldest living organisms. Nature 356:428-431.

Spradbery, J.P.; Kirk, A.A. 1978. Aspects of the ecology of siricid woodwasps (Hymenoptera: Siricidae) in Europe, North Africa and Turkey with special reference to the biological control of *Sirex noctilio* F. in Australia. Bulletin of Entomological Research 68:341-359.

Stanosz, G.R.; Smith, D.R.; Guthmiller, M.R.; Stanosz, J.C. 1997. Persistence of *Sphaeropsis sapinea* on or in asymptomatic stems of red pine nursery seedlings. Mycologia 89:525-530.

Su, N.-Y.; Scheffrahn, R.H. 1990. Economically important termites in the United States and their control. Sociobiology 17(1):77-94.

Su, N.-Y.; Scheffrahn, R.H. 1998a. *Coptotermes vastator* Light (Isoptera: Rhinotermitidae) in Guam. Proc. Hawaiian Entomol. Soc. 33:13-18.

Su, N.-Y.; Scheffrahn, R.H. 1998b. A review of subterranean termite control practices and prospects for integrated pest management programmes. Integrated Pest Management Reviews 3(1):1-13.

Su, N.-Y.; Scheffrahn, R.H.; Weissling, T. 1997. A new introduction of a subterranean termite, *Coptotermes havilandi* Holmgren (Isoptera: Rhinotermitidae), in Miami, Florida. Florida Entomologist 80(3):408-411.

Swan, D.C. 1942. The bark beetle *Hylastes ater* Payk. (Coleoptera, Scolytidae) attacking pines in Australia. Journal of Agriculture South Australia 46:86-90.

Swart, W.J.; Wingfield, M.J. 1991. Biology and control of *Sphaeropsis sapinea* on *Pinus* species in South Africa. Plant Disease 75:761-766.

Swart, W.J.; Wingfield, M.J.; Knox-Davies, P.S. 1988. Relative susceptibility of *Sphaeropsis sapinea* of six *Pinus* spp. cultivated in South Africa. European Journal of Forest Pathology 18:184-189.

Swart, W.J.; Grant, W.S.; Wingfield, M.J. 1992. Allozyme variation among geographic isolates of *Sphaeropsis sapinea*. Abstract. Proceedings, 1992 joint APS/MSA meeting, Portland, OR.

Talbot, P.H.B. 1964. Taxonomy of the fungus associated with *Sirex noctilio*. Australian Journal of Botany 12:46-52.

Talbot, P.H.B. 1977. The *Sirex-Amylostereum-Pinus* association. Annual Review of Phytopathology 15:41-54.

Taylor, K.L. 1981. The sirex woodwasp: ecology and control of an introduced forest insect. Pp. 231-248. In: Kitching, R.L.; Jones, R.E., eds. The ecology of pests - some Australian case histories. Melbourne: CSIRO.

Taylor, K.L.; Hadlington, P. 1948. Forest insects in New South Wales: The mottled cup-moth (*Doratifera vulnerans*). New South Wales Forestry Record 1:42-47.

Thorne, B.L. 1998. Biology of subterranean termites of the genus *Reticulitermes*. Pp. 1-30. In: NPCA research report on subterranean termites. Dunn Loring, VA: National Pest Control Association.

Thorne, B.L.; Carpenter, J.M. 1992. Phylogeny of the Dictyoptera. Systematic Entomology 17:253-268.

Tkacz, B.M.; Burdsall, H.H. Jr.; DeNitto, G.A; Eglitis, A; Hanson, J.B.; Kliejunas, J.T.; Wallner, W.E.; O'Brien, J.G.; Smith, E.L. 1998. Pest risk assessment of the importation into the United States of unprocessed *Pinus* and *Abies* logs from Mexico. General Technical Report FPL-GTR-104. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 116 p.

UN Statistics Division. Commodity trade statistics database (UN Comtrade).

US Census Bureau. 2000. 1997 Economic census: comparative statistics for United States.

USDA. 2000. Pest risk assessment for importation of solid wood packing materials into the United States. Draft August 2000, unpublished report. 275 p. *www.aphis.usda.gov/ppq/pra/swpm/*

USDA Forest Service. 1991. Pest risk assessment of the importation of larch from Siberia and the Soviet Far East. Miscellaneous Publication 1495. Washington, D.C.: U.S. Department of Agriculture, Forest Service.

USDA Forest Service. 1992. Pest risk assessment of the importation of *Pinus radiata* and Douglas-fir logs from New Zealand. Miscellaneous Publication 1508. Washington, D.C.: U.S. Department of Agriculture, Forest Service.

USDA Forest Service. 1993. Pest risk assessment of the importation of *Pinus radiata*, *Nothofagus dombeyi*, and *Laurelia philippiana* logs from Chile. Miscellaneous Publication 1517. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 248 p.

USDA Foreign Agricultural Service. 2003. Wood Products: International Trade and Foreign Markets Annual Statistical Trade Issue. Circular Series WP 01-03, tab 112-113.

Wang, C.G.; Blanchett, R.A.; Jackson, W.A.; Palmer, M.A. 1985. Differences in conidial morphology among isolates of *Sphaeropsis sapinea*. Plant Disease 69:838-841.

Watson, J.A.L.; Brown, W.V.; Miller, L.R.; Carter, F.L.; Lacey, M.J. 1989. Taxonomy of *Heterotermes* (Isoptera: Rhinotermitidae) in southeastern Australia: cuticular hydrocarbons of workers, and soldier and alate morphology. Systematic Entomology 14:299-325.

Weesner, F.M. 1970. Termites of the nearctic region. Pp. 477-525. In: Krishna, K.; Weesner, F.M., eds. Biology of termites, Volume II. New York, NY: Academic Press.

Wingfield, M.J.; Knox-Davies, P.S. 1980. Association of *Diplodia pinea* with a root disease of pines in South Africa Plant Disease 64:221-223.

Witcosky, J.J.; Schowalter, T.D.; Hansen, E.M. 1986. *Hylastes nigrinus* (Coleoptera: Scolytidae), *Pissodes fasciatus*, and *Steremnius carinatus* (Coleoptera: Curculionidae) as vectors of black stain root disease of Douglas-fir. Environmental Entomology 15:1090-1095.

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Naturalist Memoirs No. 6. Brigham Young University, Provo UT. 1359 p.

Woodrow, R.J.; Grace, J.K.; Yates, J.R. III. 1999. Hawaii's termites – an identification guide. Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, HSP-1. 6 p.

Wright, G.G.; Harris, J.A. 1974. Ambrosia beetle in Victoria. Forests Commission Victoria, Forestry Technical Papers 21:47-57.

Wylie, F.R. 1982. Insect problems of *Araucaria* plantations in Papua New Guinea and Australia. Australian Forestry 45:125-131.

Wylie, F.R.; Yule, R.A. 1978. Pine bark weevil. Queensland Department of Forestry, Advisory Leaflet No. 12. 3 p.

Zondag, R. 1977. Xyleborus truncatus Erichson (Coleoptera: Scolytidae). Forest and timber insects in New Zealand. New Zealand Forest Service, Forest Research Institute, Rotorua. No. 21. 4 p.

APPENDICES

APPENDIX A—TEAM'S SITE VISITS TO AUSTRALIA

In September 2001, WIPRAMET traveled to Australia as part of an assessment of pests of concern that might be transported on logs and chips of *Eucalyptus* to the United States. During that visit and from discussions with APHIS, we determined that there was a need to also assess pests that may be associated with unprocessed logs and chips of *Pinus* exported from Australia. These notes are edited from the trip report that was prepared for the "Pest Risk Assessment of the Importation Into the United States of Unprocessed Logs and Chips of Eighteen Eucalypt Species From Australia." Although that site visit focused primarily on the eucalypt resource of Australia, there was some information gathered on exotic pines as well, and that information is highlighted here, with most of the information on eucalypts removed.

CANBERRA: SEPTEMBER 12-15, 2001

WIPRAMET members Borys Tkacz, John Kliejunas, Gregg DeNitto, Harold Burdsall, Jessie Micales, Dennis Haugen, Michael Haverty, and Andris Eglitis traveled to Australia with APHIS representatives Jane Levy and Edward Podleckis. The Team departed the U.S. from San Francisco on September 10, 2001, and arrived in Sydney, Australia on September 12. The team met in Canberra for 2 days of discussions with Australian officials and then divided into three sub-teams that visited two states each for several days. Once the state visits were concluded, the Team gathered again in Canberra for a closeout session before returning to the U.S.

SEPTEMBER 12

The Team arrived in Canberra, Australian Capital Territory.

SEPTEMBER 13

The Team met with officials from Australia's Department of Agriculture, Fisheries and Forestry (AFFA). The AFFA Department includes the Australian Quarantine and Inspection Service (AQIS) and an area called Market Access and Biosecurity (MAB), which contains the Plant and Animal Quarantine Policy Division. Also present at the meeting was USDA-APHIS Area Director for Oceania, Dennis Hannapel who is an APHIS attaché in Australia. We were welcomed by Dr. Simon Hearn, Executive Manager of Market Access and Biosecurity. Dr. Hearn described the roles of AQIS (inspections) and Biosecurity Australia (scientific aspects of policy). His office has carried out a number of risk assessments for imports coming to Australia. Dr. Hearn pointed out that they have the same debates in Australia as in the U.S. over the issue of what constitutes "reasonable risk."

Dr. Hearn also discussed forestry in Australia, pointing out that there are 1.5 million hectares (3.7 million acres) of plantations in the country (70 percent softwoods and 30 percent hardwoods, mostly *Eucalyptus*). The major issues in Australian forestry are economic, environmental, and recreational. Currently, the management of forest plantations is mostly at the State level, with a number of common agreements regarding planting and harvesting developed across the tiers of government in Australia. Forestry is seen as being very important for the future of Australia.

Mellissa Wood, Database Manager for the National Forest Inventory, Bureau of Rural Sciences (AFFA), gave the Team a presentation on the forest and plantation resources of Australia. The National Forest Inventory (NFI) collects and communicates information about Australia's forests. This is a collaborative effort between the governments of the Commonwealth and the individual states and territories. NFI has been in existence for 12 years and provides a framework for the states to report information on their native forests and plantations. The data gathered, collated, and reported by NFI include the extent of native forest cover and changes in cover over time: the extent, location, and species involved in plantations; the extent and representation of forest types in conservation reserves; and the tenure of forests by region. The National Forest Inventory makes information available through GIS maps, tables and graphs.

Plantations, 1.5 mm hectares, represent 0.8 percent of the country's total forest cover. Data from this resource are managed by the National Plantation Inventory (NPI), a component of the NFI that tracks ownerships greater than 1,000 hectares (2,471 acres) in size. Data from plantation holdings smaller than 1,000 hectares are tracked through the National Farm Forest Inventory, a subset of NPI. Farm forestry represents about 5 percent of the current plantation total. Although 66 percent of the current area in plantations is in softwoods, there has been a dramatic increase recently in hardwood plantations. 62 percent of the current hardwood plantation resource is Tasmanian blue gum, *Eucalyptus globulus*, grown for short-rotation pulp production. *Pinus radiata*, grown mostly in southern Australia, represents about 74 percent of the softwood plantation resource. Most new plantations are now being established on cleared agricultural land rather than on cleared forest land. The plantation resource has increased dramatically in recent years, with 30,000 hectares (74,131 acres) planted in 1995; 55,000 hectares (135,900 acres) in 1997; and 120,000 hectares (296,500 acres) planted in 2000. 92 percent of the plantations were established since 1970; 47 percent have been planted since 1990. About 46 percent of the plantations are privately owned, including cases where the land is owned by one party but the trees are owned by another through a lease arrangement. The recent dramatic trends in plantations are toward private ownership and toward hardwood species. Much of the hardwood plantation resource is owned by Japanese corporations, and the wood will go directly there as chips once the trees are harvested.

SEPTEMBER 14

The Team met with forest pathologists Dr. Glen Kile and Mark Dudzinski at the offices of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Forestry and Forest Products in Yarralumla, A.C.T. Mr. Dudzinski has worked on *Phytophthora cinnamomi* in the jarrah (*E. marginata*) forests, banksia woodlands, and native heath lands in southwestern Australia; on foliar pathogens of eucalypts and acacias in Australia and Southeast Asia; and on issues relating to stem defect in residual trees following stem wounding during mechanized thinning of regrowth eucalypt forests in southeastern Australia. Dr. Kile, Chief of this research division of CSIRO (Forestry and Forest Products), serves as the Chairman of the National Forest Health Committee. This Committee is currently focused on developing a generic incursion management strategy for Australia.

Dr. Kile discussed some foreign organisms that are of concern to Australia. He expressed an interest in pine pitch canker from California. Current pest problems of concern in Australia include some mysterious nematodes in *Pinus radiata* near Melbourne and a fire ant problem in Queensland that is the subject of an eradication program. These recent problems have led to increased funds to manage the country's borders for pest introductions. Another problem of significance in forestry is Dothistroma needle disease [caused by *Dothistroma septospora* (Dorog.) Morelet] in *Pinus radiata*. This disease is a periodic problem that limits *P. radiata* in high rainfall areas. *Dothistroma* has not yet spread to Western Australia or New South Wales, and a program is now underway to breed for resistance to the disease. In February of 2000, *Bursaphelenchus*-like nematodes were found in a dying tree in the suburbs of Melbourne. These have not yet been identified, and a *Monochamus* vector has not been found, even though there have been some *Monochamus* interceptions associated with solid wood packing material from China. An interception unrelated to the nematode is of a new species of the wood-boring beetle *Arhopalus*. Australia is very concerned about Asian gypsy moth and is carrying out pheromone trapping near ports and high-risk areas. In addition, a post-barrier surveillance program is in place for the Asian gypsy moth.

Dr. Kile pointed out that, since 1971, there have been 5 to 6 million tonnes of chips exported to Japan, and no pathogens have been reported during that time period. Dr. Kile felt that wood decay fungi would be even less of an issue in plantations than in regrowth forests because coppice growth is likely to be less common than replanting with genetically improved material. He informed us that Tim Wardlaw is working on wood decay fungi associated with regrowth in Tasmania.

We learned that many exotic tree species have been planted in Canberra since 1913, and that some have experienced pest problems. Dieback has been noted on *Pinus ponderosa,* and *Botryosphaeria* has been found on *Sequoia* sp. Other significant exotics include the elm leaf beetle (*Pyrrhalta luteola*) in Victoria and a canker fungus on *Platanus* street trees. An aphid native to California, *Essigella californica*, has become widely established on *Pinus radiata* and is problematic in the Mt. Gambier area where pines are under stress. We learned that Rob Floyd (CSIRO) has a student working on this aphid.

The Team inquired about other organisms that have adapted to *Pinus radiata* in Australia. Dr. Kile responded that Australia's situation is comparable to New Zealand, where all of the organisms associated with *P. radiata* are ones that have been introduced. He listed the aphid *Essigella californica*, *Ips grandicollis*, *Sirex noctilio* and *Dothistroma septospora* as the agents of greatest concern on Monterey pine. Of all these organisms, Mark Dudzinski felt that Dothistroma needle blight was the most important. *Armillaria* has not been found on *P. radiata* in Australia, even though *A. luteobubalina* may occur where *P. radiata* has been planted.

September 15

The team spent a day off in Canberra.

September 16

Each of the three sub-teams began their State site visits. Borys Tkacz, Michael Haverty, and Jessie Micales departed for New South Wales and Queensland; Harold Burdsall, Jane Levy, and Andris Eglitis traveled to Victoria and Western Australia; and Dennis Haugen, Gregg

DeNitto, John Kliejunas, and Ed Podleckis traveled to Tasmania and South Australia.

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The team that traveled to New South Wales and Queensland was composed of Dr. Jessie Micales, Dr. Michael Haverty, and Mr. Borys Tkacz.

SEPTEMBER 16: CANBERRA TO EDEN

In the morning, we met Jack Simpson, a plant pathologist with the Research Division of the State Forests of New South Wales (SFNSW). Emmanuel Mireku from Biosecurity Australia accompanied us. We drove south from Canberra to Cooma, east-southeast to Bega, then south to Merrimbula and Eden.

The first part of the trip between Canberra and Cooma took us through woodlands and grasslands with many sheep and cattle. *Pinus radiata* was being grown as shelterwood for livestock refuge. Many old, large *Eucalyptus* trees in pastures had *Amyema* mistletoe infestations, an indication of tree stress.

We stayed overnight in Eden along the southern coast of New South Wales.

SEPTEMBER 17: EDEN TO COOMA

We first went to the offices of SFNSW in Eden and met Phil Goldberg, a staff forester. He guided us to the Nadgee State Forest outside of Eden. Because of danger from wildfire, the native forests are highly managed by thinning and prescribed burning. Eucalypts stand up well to fire damage, so thinning and hazard reduction burns are conducted throughout

the rotation. The conservationists object to this practice and would rather see little to no management. Currently there are heavy restrictions on logging, including a ban on logging within 50 meters (164 feet) of a stream or known endangered species. Logging permits involve approval from three different agencies and are expensive to obtain. Thinnings are generally sent to chip mills. The logging is done by private contractors.

We stayed overnight in Cooma.

SEPTEMBER 18: COOMA TO TUMUT TO CANBERRA

We drove from Cooma toward Tumut on the Snowy Mountain Highway. We passed through the Kosciuszko National Park in which all non-native species have been removed. Not much fuel reduction management is being done in any of the national parks. As we drove through the Snowy Mountains, we saw phasmid defoliation of *E. delegatensis* (alpine ash) and *E. pauciflora* (snow gum), which is not a commercial species. Acacia rust, caused by *Uromycladium*, was also present in the plants along the highway. There were also large plantings of *P. radiata* along the ridges of the mountains. They were showing evidence of *Dothiostroma septosporum* colonization, but there were obvious variations in resistance. The pines are very sensitive to microclimate variations. In many cases, one observes *Dothiostroma* in the valleys, but not along the ridgetops. Many U.S. diseases and insects of radiata pine are now present in Australia, including *Ips grandicollis*, *Ceratocystis*, and *Ophiostoma* stain. Additional insects and diseases of pines could be imported easily if Australia continues to import whole logs (with bark) from Canada and the U.S.

In Tumut, we visited the SFNSW office and then went to a mill operated by Weyerhauser Australia Pty. Ltd., where we were hosted by Peter Stiles. This mill produces sawtimber exclusively from *Pinus radiata*. All logs are initially scanned, debarked, and sorted into bins by size. When enough logs are in a certain bin, they are moved to the sawmill for a sawing run. The logs are generally in the logyard for only three to five days before processing, but they can sit in the bush for two to three weeks (less time in the summer) before being brought into the mill. Ideally, they would like the logs to sit in the bush for less than a week because of the rapid development of bluestain. The logs that we saw were very clean, with little insect damage, decay, or bluestain. The debarking operation was about 90 to 95 percent efficient, which is not an issue for lumber production. This could cause problems if raw logs were imported to the U.S. as even small amounts of bark can harbor the three types of bark beetles found in Australia, *Ips grandicollis*, *Hylastes ater* (Paykull) and *Hylurgus ligniperda* (Fabricius). The latter two species are from Europe; *H. ligniperda* has recently been introduced to New York State in the U.S.

Once enough logs of a particular length and diameter are accumulated, they are sawn to fill a specific order. Sawing and sorting were largely automated. Stress grading is done automatically by the computer. The rough boards were then kiln-dried overnight at 140°C with temperature and humidity regulated by computer. Railroad ties ("sleepers") are dried for 48 hours. The target moisture content for all material is 12 percent. The mill has 11 kilns. Logs are quite variable in their moisture content, especially in the winter, and comprise a mixture of young and old material. Therefore, computer regulation is necessary to achieve uniform drying. Some of the sawn timber is treated with CCA and is dried in a separate kiln. The kilns can treat up to 600 cubic meters (21,189 cubic feet) of wood with CCA per day.

After kiln-drying, the boards are finished in the planing mill, where they are sorted, graded, and wrapped for shipment. The amount of wood converted to lumber is about 40 percent of the original 400,000 cubic meters (14.1 million cubic feet) of logs per year. Often, the centers of the logs cannot be cut into timber because of the high percentage of juvenile wood that would cause extensive warping and cracking. Approximately 40 percent of the material is recovered on-site and burned for energy. Off-cuts are either chipped or the fiber is sent to a new composite board factory. All of the lumber is sold for domestic construction.

We then met Duncan Watt, Planning Forester with SFNSW, and traveled to pine plantations near Tumut. The primary planted species is *P. radiata*. The Tumut Region contains 84,000 hectares (207,569 acres) of radiata pine on state lands and 24,000 hectares (59,305 acres) on private lands. This is half of the total population of radiata pine of NSW. Currently, there are no root rot or heart rot fungi of *P. radiata* in Australia. It would be very detrimental if fungi such as *Phellinus pini* or *Veluticeps* spp. were to be introduced. At the plantation, we saw test plantings of five to ten different pine species, including *P. lambertiana* (sugar pine), *P. ponderosa* (ponderosa pine), and *P. jeffreyi* (Jeffrey pine). At 3,000 feet (1,000 meters) elevation, radiata pine suffers a large amount of snow damage and is not the ideal species for planting. The test plots were set out to determine if other alternatives would be better, but the market demand is for radiata pine. Mills no longer favor *P. ponderosa* because it takes too long to dry.

Within the plantation, the stands were being thinned and the logs usually sit out in the log decks for one to seven days. It is best to get them out of the forest quickly because of bluestain fungi. There are rarely any internal defects in these logs, although needles are often damaged by Dothistroma blight. The most important species of bluestain fungus is *Sphaeropsis sapinea*, but introduced species of *Ceratocystis* and *Ophiostoma* are also common. Blue stain in the wood decreases the quality of the logs for chips as more processing is required to brighten the fiber. In this area, *Hylastes ater* bark beetles were swarming all over the logs that had just been cut. These beetles can carry ophiostomoid fungi. Another problem beetle is *Hylurgus ligniperda*.

During the thinning process, the branches, needles, and flared butt ends of the trees are left in the forest until replanting. This helps with erosion control. At planting, the slash is piled and burned.

At a second stop, the forest was primarily composed of *P. contorta* (lodgepole pine) and a species of *Picea*. Many of these trees had died from drought and herbicide damage. Cultivating other species, including the five-needle pines: *P. monticola* (western white pine), *P. lambertiana* (sugar pine), and *P. strobus* (eastern white pine), in this area had been attempted, but changing to these species will probably not work because of market demand for extensive quantities of a single species (i.e., *P. radiata*). The 70-year-old sugar pines were immense. New sugar pine cannot grow to this size in the U.S. because of white pine blister rust caused by *Cronartium ribicola*. Unfortunately, *Ribes* is imported into Australia as an ornamental, so the introduction of *C. ribicola* is a good possibility.

In ponderosa pine, we saw tip and shoot blight caused by *Sphaeropsis*. *Sphaeropsis* is also found on radiata pine and is very common in drought-stressed and hail-stressed trees. Root infections can also occur when trees are under drought stress. Secondary fungi then move in, including *Phomopsis*. Crown damage can also occur in the crown due to cold damage. We saw numerous trees with extensive dieback in the crown, but were not able to determine the cause. The lower branches appeared not to be so affected. It seemed more extensive than one would associate with Dothistroma needlecast or the Monterey pine aphid, *Essigella californica*.

We then visited a clearcut of radiata pine. The slash was left in the field and is later windrowed and burned. The area is then replanted in the following year. These trees are thinned when they are 12 years old. At this time, they are the proper size for the chipper. Only one thinning is made. Again, there was much discoloration in the crowns of the trees. Some of the trees were 32 to 33 years old and were quite large. The logs in the stack were very clean with no indications of insects or disease. The bark is kept on the logs in the bush and removed at the mill.

We returned to Canberra in the evening.

SEPTEMBER 19: CANBERRA TO GRAFTON

In the morning, we traveled to Hume, ACT, on the outskirts of Canberra and visited Integrated Forest Products, where we were hosted by Paul Job, the Sawmill Production Manager. This plant is currently processing both *P. radiata* for the domestic structural timber market and *P. ponderosa*, some of which it exports as kiln-dried lumber to the U.S. The two species

are kept separate throughout the production line. All logs are from the Canberra region.

Bob McGovern, the Log Yard Manager, showed us the mill. Ponderosa pine are debarked. Blue stain will develop in ponderosa pine if it is kept too long before kiln drying. In the summer, the pine logs need to be processed within two weeks, but they can go as long as five weeks in the winter. No decay or borers were observed in the log yard; the trees appeared very healthy. There is a termite problem in Australia with structural lumber made from radiata pine, but not in trees on the stump. The radiata pine logs are dried at 140°C, but the ponderosa pine must be dried at a lower temperature (100°C) to prevent internal checking and collapse of the boards.

The trees arrive from the state government department and are measured for their diameter and width. They are scanned with a computer and also measured by hand. Samples are taken by government inspectors on Tuesdays and Thursdays as spot-checks to make sure that the volume calculations are accurate. They usually sample three to five loads. Some logs are rejected by the mill. The size limit for this mill is 580 mm (22.8 inches) in diameter – those that are larger are rejected and taken away to another mill for cutting as big logs will destroy their saw. The logs are sold by weight, so it is important to return the logs as soon as possible so they do not lose too much weight from drying. They are resold by the state to a different company that will turn them into railroad sleepers. Logs will also be rejected if they have defects or if they are too short. The rejected logs are stockpiled for two weeks and then collected by the state supplier and sent for chips or to other yards that can handle bigger material. Some logs need trimming if branches are left on. The waste and undersized material is chipped and sold to a pulp mill. A new plant will be opening soon that will be closer to this one.

The logs are debarked and sorted into different bins by size. Sometimes the base of the log will flare out. These will be sawn off by the machine and then sent back through the debarking process. The debarking machine can handle 130 logs per hour. The bark is carried by a conveyer belt underneath the log carriage and dumped onto a waste pile. This is sold to nurseries for mulching material. Undersized material is sold to a neighboring pallet manufacturer.

Once the logs are debarked, they are kept off of the ground and are stacked until enough accumulate of a certain size to be sawn. Ponderosa pine logs are kept separate from the radiata pine logs. The logs in the saw yard should be turned over every two weeks to reduce the development of blue stain. Some logs may be kept as long as three months while waiting for other logs of the same dimension to collect a sufficient number for sawing. During this time, the wood will darken and a little blue stain will start coming onto the surface of the log. There were very few obvious insect problems on the logs. Debarking technology is not 100 percent efficient, with some bark remaining around the branch stubs and irregularities in the bole.

The mill is currently running two shifts to operate the dry kilns and three shifts for the planer. *Pinus radiata* is dried at 140° C with a 12 hour drop; *Pinus ponderosa* needs 33 hours at 100°C. In older kilns, this would have taken 65 hours. *Pinus ponderosa* is especially subject to splitting, so water is added back to prevent overly rapid drying. After kiln-drying, the wood is run through a planer. Scraps of wood that would normally be discarded are finger-jointed together to make a salable product.

We then flew from Canberra to Grafton where we stayed overnight.

SEPTEMBER 20: GRAFTON, NEW SOUTH WALES

The Team spent the day collecting information on the *Eucalyptus* resource and, in the evening, flew to Brisbane, Queensland.

SEPTEMBER 21

We visited the Queensland Forestry Research Institute (QFRI) in Indooroopilly, Queensland, a suburb of Brisbane. We met with Drs. Judy King, Senior Entomologist, Forest Protection Program, and Ross Wylie, Program Leader and Forest Entomologist, Forest Protection Program. The QFRI is a state government organization that is partly supported by external funding. They are a commercial institute and are externally funded by industry. They just received a major contract to bait large portions of Queensland for fire ants. The Institute employs about 130 people: half of these are scientists and the rest are research support. They are housed in two locations. The majority of scientists are split between Brisbane and Gympie, about 180 km (111.8 miles) north of Brisbane. Another 10 scientists are 2.5 hours away in Atherton in northern Queensland. The northern facility is more concerned with tropical problems.

The Institute has six primary programs: Genetic Resources, Sustainability, Silviculture, Timber Protection, Forest Protection, and Wood Products. Forest Protection has four entomologists, three pathologists, and two in forest health surveillance. Their main work is in forestry, and they provide technical advice and research on native pines (i.e., *Araucaria* spp.), cypress, and the hardwoods

of Queensland. They have a web page with information about diseases and insects at http://www.dpi.qld.gov.au/forestry/.

They told us that there was very little radiata pine in Queensland, but there were more tropical conifers, such as hoop pine (*Araucaria cunninghamii*). There is some radiata pine on the southern border with New South Wales. Pines are being used for chips, but *Eucalyptus* are not. This is a political decision since the public does not want to turn native trees into wood chips. In recent years, the housing market in Queensland has been quite bad. Several sawmills have closed down for weeks at a time because of the low demand for lumber.

In Queensland, there is an agreement between the Greens (i.e., environmentalist groups) and the timber industry to phase out harvesting of native trees in favor of plantation trees over the next 20 years. These groups are working together to form a hardwood plantation industry. The Institute is doing research on how to establish a hardwood industry within the next 20 years. They have established substantial lists of pests of these species for analysis.

We then went to the AQIS Queensland Office at the Port of Brisbane and met with Bill Crowe, Senior Quarantine Entomologist. He told us that all timber that is imported into Queensland is already debarked and is fumigated with methyl bromide upon arrival. Unfortunately, the methyl bromide does not penetrate deeply into the wood. AQIS has intercepted some pests from packing material and dunnage, including *Monochamus alternatus*, a wood-boring beetle. Once a beetle is detected in one container, all of the other containers from that source are tracked down and checked. To monitor for pests, pheromone traps are placed in the port area, and any dead trees in the area are felled and examined. AQIS

has isolated two species of the *Bursaphelenchus* nematode, but neither of these has been *B. xylophilus*, the pinewood nematode. There have been no interceptions of Asian longhorn beetle in Brisbane, although there were one or two interceptions in Sydney. Monitoring measures collect large quantities of beetle larvae that are very difficult to identify.

We then toured a chip mill at the Port of Brisbane called "Queensland Commodity Exports." Our host was Andrew Dawson. The mill is currently chipping *P. elliottii* (slash pine). This company is a partnership of three Asian companie, and is contracted to sell chips to Japan. In the future, the company is planning to switch to eucalypt chips with the aim of acquiring 400,000 tonnes/year from plantations. The mill is not planning on shipping any chips to the U.S. as is serves the Japanese market exclusively.

Currently, the company receives chips as either mill residue (approximately 40 percent) or as whole trees that are chipped on-site (approx. 60 percent). In the past, debarking and chipping were performed in the field, but volumes were too low to sustain the operation. Trucks with mill residue are turned up on end for discharge of chips. A truck can contain 25 tonnes of chips, and it takes 16 minutes to unload a single truck. The chipper is designed for small-diameter material and can handle over 1,000 tonnes per day. The logs are only kept in the yard for one day. They are debarked, and the bark is sold for landscape material, while the sawdust is sold for animal bedding. After debarking, the boles are chipped. The chips pass by a magnet to remove any metallic objects. They are then passed through a sizing screen, and anything oversize is sent back to the chipper. Small material and sawdust are collected, and properly sized chips are carried by conveyer belt out to the chip pile.

The screener can handle 200 tonnes of chips per hour. The chip pile holds about 45,000 to 50,000 tonnes of chips. The ships hold 36,000 to 40,000 tonnes and take 50 hours to load. This is done by pushing the chips into a collection hole by the chip pile. They are then carried up through a series of conveyors to the ship. Before loading, the chips are automatically sampled and the amount of bark, decay, size of the chip, and fiber analysis (percent moisture) determined. This is important to determine the value of the chips loaded onto the ship as they are bought based on weight.

The logs that we observed did not show signs of much insect or disease damage. There were a few old *Ips grandicollis* galleries (native to the U.S., and imported to Australia). Some of the chips had some blue stain, which can develop in just a few days. Temperatures within the chip pile are quite hot and have a steaming effect according to the mill operators. They have not had any problems with combustion. The chips are usually exported within three months after chipping. Recently, the chips have stayed on the chip pile for about six months due to lack of demand for the material in Japan as a result of their downward economic turn. If they are kept too long, the chips oxidize and turn dark. This is bad because more bleaching chemicals are needed to brighten up the pulp. The chips lose moisture in the pile – usually from about 50 percent moisture down to 45 percent moisture. One problem with the loss of moisture is that the chips are lighter that expected, and the ship does not ride as deep in the water as it should. There were no reports of the chip insects as we observed in the mill in Eden.

Exporters are trying to increase the export of hoop pine from the port of Brisbane. Currently, very few logs are imported through this port—only some specialty logs from New

Guinea—though some chipboard is exported. No North American logs arrive in Brisbane.

September 24

In the morning, we met Bruce Brown and Judy King, who took us to Grant Timbers in Woodford, Queensland. On the way to the mill, Bruce told us about his database on microorganisms of *Eucalyptus*. It currently has 20,000 records, and he printed out copies and gave them to us. We discussed several of these pathogens in more detail. *Armillaria pallidula* was originally collected by Brown. It was associated with losses in a *Eucalyptus* plantation over several years, and fruited in May for several years in a row. It hasn't been collected since. Although *Armillaria* can be a problem in certain local situations, in general it is not a major problem in Queensland. *Armillaria* is moderately significant in fruit orchards and ornamental plantings in the granite belt area of southeast Queensland.

We then went to the Weyerhaeuser Australia Pty Ltd. Mill in Caboolture, Queensland. On the way, Bruce told us how a lot of acreage was burned in the mid-1980s. The wood was salvaged, but because of the massive quantities collected, it has to be stored under sprinklers to prevent the infestation by borers. The trees were mostly *P. elliottii*, *P. caribaea*, and some other species of pine. After about 15 months under wetting, severe decay by *Rigidoporus lineatus* destroyed much of the wood. It is thought that the basidiomycete started to grow after bacteria had destroyed the pit membranes, allowing the decay fungus easy access. Literature reports had suggested that *R. lineatus* can grow under conditions of limited oxygen.

At the Weyerhaeuser mill, we met Craig Morris, Resources Manager. Weyerhaeuser

acquired the mill in 2000; it was formerly an Australian-owned mill. It produces approximately 350,000 cubic meters (12.4 million cubic feet) of wood per year. Weyerhauser also has an export chip business at the Port of Brisbane (which we visited on September 21) that exports 250,000 cubic meters (8.8 million cubic feet) of wood chips per year. The chips are produced both from pulp logs and as byproducts of this mill and others.

The trees are obtained from private forests that have contracts with the mill. Growers own the trees, but not the land, and the resource is becoming limited. Initially Weyerhauser had access to 20,000 ha (49,421 acres) of trees, but this has dropped down to 3,000 to 4,000 hectares (7,413 to 9,843 acres). The land is essentially being cleared for real estate due to the high value of shorefront property. The trees are almost entirely *P. elliottii*, but they are slowly changing to *P. caribaea* and clonal hybrids of *P. elliottii* and *P. caribaea*, which are propagated from cuttings rather than being grown from seed. The principal product is structural timber for the domestic market. The mill has been hit hard by the downward turn in housing and has reduced production from the normal two shifts to one shift. The company does not plan to ship raw logs to the U.S. because this would not be economically feasible. The offcuts are burned as fuel for the boilers that heat the dry kilns. The wood is dried at 116°C for eight hours, although the internal wood does not achieve that temperature. The current requirement to kill *Sirex*, for example, is a core temperature of 65°C for two hours. The mill wants the dry kiln hot enough to "plasticize" the wood in order to set it straight without warp. The target moisture is 8 to 12 percent, and the wood later stabilizes at 13 percent. The wood is kiln-dried immediately without sitting around for air-drying in order

to have uniform moisture content within the kiln charge.

We walked through the log yard, which holds enough logs for about a week's worth of sawing. The logs are debarked in the yard and might sit for a while before sawing. The log supply is difficult to maintain in this region because much of the bush is very wet during certain times of the year, making it difficult to transport logs. Blue stain can develop within a week and is often associated with wounds in the bark caused by the mechanical harvesting. Logs are transported from as far away as 200 km (124.3 miles). Transport of logs is a major expense. In the log yard, the trees appeared very clean and were nearly free of insects and pathogens. Some logs did have extensive blue stain. Bruce explained later that the normal blue stain fungus was *Sphaeropsis sapinea*, but species of *Ceratocystis* started to show up once *Ips grandicollis* was introduced from the U.S. *Ips* is currently restricted to southeastern Queensland. This blue stain is probably *Sphaeropsis* because there was no sign of beetle activity. Needles and branches arrive on the cut logs, but these are removed during the debarking process.

We then followed the process of cutting the debarked logs into boards, which was done with multiple bandsaws. The boards were sorted and stacked into piles with stickers between board courses for kiln-drying. The mill has four kilns available for drying and some older kilns for reconditioning.

After kiln-drying, the boards are planed with a high-speed, 30-weight "molder." They are sorted, graded, and stacked by hand. The mill will be putting a new machine in to do this and make the process more automated. Everything is tracked by computer, and the final packs are labeled and barcoded.

We then visited a pine plantation in Beerburrum/Beerwah with Denis Maloney, with the Department of Public Industry (DPI) Forestry group. The DPI is a self-sustaining organization. The money obtained by selling the trees pays for expenses, land acquisition, and plantation expansion; a payment is also made to the government. The plantation is currently planting *P. elliottii* X *P. caribaea* hybrid cuttings. The pine is cut and processed in the field leaving the slash behind. The material being harvested during our visit was 36-year-old *P. elliottii*. Only the new plantations are hybrids.

After the trees are harvested, as much litter is left in the field as possible. It is generally chopped up and many of the old stumps pushed up. In wet, low sites, windrows are built up and new trees are planted at 5-meter (16.4 feet) by 2.4-meter (7.9 feet) intervals. One thinning is done at about 17 years, and the entire plantation is harvested at 20 years. The goal is to have about 450 stems/hectare (2.47 acres, or about 182 stems/acre) for the final cut. These trees are selected for wood properties and fast growth. The company is sacrificing a little size by harvesting before 30 years, but it is thought to be worth it in productivity. Different levels of cultivation are done depending on the wetness of the site. In very wet areas, continuous mounding is done with water between the rows. Better-drained sites have strip cultivation where the trees are planted behind a skidder at 5-meter intervals. Before planting, the sites are cleaned up with Roundup®. The seedlings are containerized and can be planted all year with the heaviest planting occurring from December to August during the summer rains. After planting, monoammonium phosphate is applied as a fertilizer. Weed growth is prevented by a top spray of simazine, which prevents weed seeds from sprouting, and then the area is treated

again with Roundup® in late spring. The weeds that do grow are kept in check with contract mowing. In the past, the trees were pruned, but this may be discontinued because the trees grow so quickly that it is hard to keep the core trunk to 15 cm (5.9 inches). In the past, the trees were pruned at age four to five years to a height of about 5 meters (16.4 feet). At age 5, the first prescribed burn is done. The trees are about 10 meters (32.8 feet) high at this time. The canopy closes within six to seven years.

Ips is known to attack stressed trees, including those affected by fire damage and mechanical wounds. After a major fire, *Ips* can get into trees within six weeks. After *Ips*, the *Xyleborus* pinhole borer invades trees that are very sick or dying. No evidence of *Dothistroma* was seen, although it could develop over a long protracted winter that is cold and wet. *Sphaeropsis* does not seem to be a major concern: as a shoot blight, it is usually associated only with stressed trees. *Pinus caribaea* does seem to be susceptible to *Sirex*, but that has not yet been introduced to Queensland. *Pinus elliottii* is resistant to *Sirex*, and the *P. elliottii* X *P. caribaea* hybrids are just being tested. *Phytophthora* has been found on isolated spots and in nurseries, where it stays active for many years. A government plan will shortly be released that deals with managing for *Phytophthora*. This may change some forestry practices. It is a national plan under endangered species legislation, and has been about five years in the making. It is not known what the effect will be on Queensland forestry.

SEPTEMBER 25

The Team spent the day learning about several local eucalypt species and hoop pine, *Araucaria cunninghamii*.

SEPTEMBER 26

The team returned to Canberra.

VICTORIA, WESTERN AUSTRALIA: SEPTEMBER 16-25, 2001

SEPTEMBER 16

The WIPRAMET sub-team of Dr. Harold Burdsall, Jane Levy, and Dr. Andris Eglitis flew from Canberra to Melbourne.

SEPTEMBER 17

The sub-team was met at the hotel by Mr. Simon Murphy of the State Department of Natural Resources and Environment. Mr. Murphy is head of the Forest Science Center and manages the Research and Development Group at the Heidelberg facility of the department. Mr. Murphy led our tour through forested lands northeast of Melbourne, including the areas of Toolangi and Narbethong. Along the way we had an opportunity to learn more about the ecology and management of eucalypt forests from Mr. Murphy.

We traveled to Kingslake West where we met Dr. Ian Smith, Forest Pathologist and organizer of our trip in Victoria, and Mr. Nick Collett, Entomologist. Both work for the State Department of Natural Resources and Environment in Heidelberg, Victoria. They were accompanied by Paul Barber, a graduate student in forest pathology at Latrobe University. We drove to a plantation of 3-year old *Eucalyptus globulus* that has been established as a progeny trial to examine the performance of 44 families of seed sources.

In the same area, we saw plantations of *Pinus radiata* and inquired about its uses and the

associated pest problems. Monterey pine has been planted extensively in the area, with the primary use being for sawlogs that yield structural grade framing lumber, studs, and trusses that are easier to use than eucalypts. In the past, native forests were cleared to make room for plantations of *P. radiata*. The recently introduced aphid (*Essigella californica*) is now very widespread in the country, occurs in the Kingslake area, and causes some defoliation. Host trees are most susceptible from 15 years of age onwards; younger trees are generally not defoliated. Damage appears to be confined to old needles and is greatest in the top half of the tree. There also appears to be a connection with nutrient levels; aphid damage increased with increased soil nitrogen. We inquired about bark beetles and learned that *Ips grandicollis* has been in the Mt. Gambier area since 1983 and produces four generations per year there. Apparently, the beetle confines its attacks to slash and does not usually infest living trees. Two other exotic species of bark beetles, *Hylurgus ligniperda* and *Hylastes ater*, breed in old slash and sometimes feeds on seedlings. However, they are not considered more than a local nuisance in Victoria. Nick Collett pointed out that as long as the timing of slash creation is managed, then these beetles do not present a problem.

Next, the team traveled to Marysville to visit plantations of *P. radiata* that are currently managed by Hancock Victorian Plantations Pty Ltd. The plantations were first established in 1938 by the state government and until recently were managed by the Department of Natural Resources and Environment. Many of the plantations have been converted into private holdings such as Hancock. In some cases, the trees are owned by the private company while the state retains ownership of the land and leases it to the company. After the trees are harvested, the land reverts back to the state.

The Hancock holdings in the Marysville area total 6,000 hectares (14,826 acres), of which 4,000 hectares (9,884 acres) are planted in *P. radiata*. The trees on these lands are either very old or very young. Many of the older stands were not thinned because of prevailing market conditions at the time. Given the fact that thinning had not occurred on time, we inquired if *Sirex noctilio* had been a problem in these plantations. We learned that this insect was a big problem in Victoria in the 1960s and in the Mt. Gambier area in the 1980s, when over one million trees were killed. Currently, a trap tree program originally developed by Fred Neumann is being conducted in cooperation with the Forest Science Centre. The trapping calls for the weakening of trees by injecting them with banvel herbicide and cutting them after the flight period of the wood wasp. In the Marysville plantations, some damage has occurred from *E. californica*, and in some cases a phosphorus deficiency has aggravated this damage. The older trees were currently being harvested with a four-day period between felling and transporting of the logs. Tree felling is done with a harvester-forwarder with a chainsaw blade. The trees are partially debarked on site, with further debarking done at the port. Slash is removed fairly promptly after the harvest. Typically, harvesting operations can be carried out all year using ground-based equipment. The second rotation is beginning on leased lands, with hand-planting between May and August (1,100 stems per hectare [445 stems per acre]) followed by an herbicide treatment 6 weeks later. A 30-year rotation is normal for softwood sawlog production. Hancock's holdings total 150,000 hectares (370,657 acres) of plantations, which includes eucalypts (*E. globulus* and *E. nitens*) for fiber production, as well as Monterey pine.

Other pest problems that were discussed in connection with *P. radiata* included the

nematode that has been found in the Melbourne area. At the same time, entomologists intercepted a longhorn borer, *Arhopalus* sp., a beetle that infests dead and dying trees. Dothistroma needle disease was extensive in Victoria during the 1970s and 1980s. Cuttings from resistant trees are being used in anticipation of an increased Dothistroma problem in the next rotation.

SEPTEMBER 18

The Team traveled to Geelong to the port facility at Corio Bay. The port has traditionally been used for trade in wool and wheat, and now handles wood chips as well. We were met at the port facility by Steve Roffey, Resources Manager for Midway Proprietary, Ltd. His company ships *P. radiata* logs through the port to Korea, Japan and India. The company was formed in 1980 by sawmillers from Victoria who contracted with the Japanese firm Mitsui to provide chips for export. Midway Pty Ltd sent its first shipment of hardwood chips to a Japanese paper company in 1986. In 1991 the company obtained residual roundwood, supplied by a network of sawmills, and in 1995 diversified into pine plantations. Now Midway owns 10,000 hectares (24,100 acres) of *P. radiata* plantations. In a joint venture they also established plantations of *E. globulus* (currently 3,500 hectares [8,649 acres] with a goal of 8,000 hectares [19,768 acres]) for export chips. Some plantation lands are owned by Midway, and other lands are leased. All of the holdings are within 150 km (90 miles) of Geelong. Eucalypts are currently being planted where Monterey pine is harvested. The cost of reestablishing a plantation is $1,700 per hectare ($688 per acre), with an eventual yield of 800 tonnes of product per hectare. *Pinus radiata* is grown on a 30-year rotation for saw logs, and *E. globulus* is grown on a 12-year rotation

for pulp logs. The current harvest rate for *P. radiata* is 170,000 cubic meters (6 million cubic feet) per year; 22 percent for domestic use, 24 percent for export sawlogs, and 54 percent for export pulpwood. Annual export volumes have steadily increased from 1985, to 700 metric tonnes in 2000. Midway Pty Ltd only exports chips, and other companies ship their logs to Japan. The softwoods are transported from the forest with bark on, and the bark is removed at the port with a chain flail. Less than 0.75 percent of the chips contain bark and the bark constitutes 0.4 to 0.5 percent of the chip weight. Eucalypts are not debarked at the port; the bark generally comes off easily during harvest (except during two months in the summer). We were told that there is very little bark that goes into *Eucalyptus* chips; even less than for softwood chips. Chips are made from solid wood only; if decay is found, the log is still processed but the contractor is notified of noncompliance.

Steve Roffey inquired about current regulations for treatment of wood, and Jane Levy explained the procedure that is being employed in Chile for *P. radiata* chips. The chips are sprayed with chlorpyriphos and a fungicide as they are being loaded onto the ship. *Eucalyptus* logs could be brought in only if they are treated with a heavy dose of methyl bromide, so that is not currently being done. We inquired about the turnover rate of chip piles and logs handled by Midway. It is possible to stockpile two shiploads of hardwood chips, and at most, a load of chips would be three months old by the time it is loaded. As such, there may be considerable heat generated in the piles. Log stock also normally has a 3-month turnaround. Some departures will occur outside of that timeframe, given that the harvesting period is only from October to May. Thus, some hardwood material may be held for nine months to provide an even

flow. Softwoods are most typically on a 6-week turnaround cycle in order to minimize bluestain.

The team also visited another facility in the port that deals in logs of *P. radiata*. Mr. Ian Sedger from Softwood Plantation Exporters (SPE) discussed the company's operations and pointed out that they ship 1.3 million metric tonnes of logs per year from the Port of Geelong. The company has a four-week turnaround on *P. radiata* stock shipped to India and Korea, primarily for core veneer. They also ship logs for other companies including some from New Zealand. Additional species exported by SPE include *P. ponderosa*, *P. pinaster*, *P. elliottii*, and *Pseudotsuga menziesii.* We inspected some of the pine logs at the site and found evidence of bark beetle galleries and late-instar larvae that appeared to be *Ips grandicollis.* Ian Sedger said that he had also seen associated woodborers in the forest. Ian Smith pointed out that the woodborer *Arhopalus* has also been seen in association with *P. radiata*. When markets are down, the logs are sometimes kept on site for four to five months so that they will dry out and will be easier to sell at a lighter weight.

September 19

The team met with personnel from the Institute for Horticultural Development. The Institute is part of Agriculture Victoria, which is a division of the State Department of Agriculture, Energy and Minerals. The Institute is located in Knoxfield, Victoria, and provides diagnostic services to various individuals and agencies, including AQIS. The Institute maintains a collection of insect and disease specimens that include organisms associated with agriculture and forestry in addition to horticulture. We met Mr. Gordon Berg, Manager of Crop Health Services, James

Cunnington, Pathologist, Dr. Mali Malipatil, Senior Systematic Entomologist for Crop Health Services, and Paul Barber, Pathologist from Latrobe University. We discussed our lists of "Pests of Concern" with these specialists from the Institute and University and were shown some of the Institute's insect and fungal specimen collections.

September 20

The team traveled from Melbourne to Perth, Western Australia. We were met at the airport by Dr. Richard Robinson, Pathologist, (our host for the Western Australia portion of the site visit) and Dr. Janet Farr, Entomologist. Richard and Janet both work for the Science and Information Division in the Department of Conservation and Land Management (CALM) for the State of Western Australia.

September 21

In the morning, the team went to the offices of CALM in Perth and met with several people from the Forest Products Commission. Commission members present at the meeting were Terry Jones, Manager of Industry Development, Trevor Butcher, and Dr. Graeme Siemon, Timber Scientist. CALM members in attendance included Mike Stukely and Colin Crane. Also present at the meeting were Dr. Elaine Davison, Mycologist, Curtin University of Technology, Mike Grimm, Quarantine Entomologist for AQIS, Brea Read, Forest Industries Federation of Washington, Dr. Giles Hardy, Pathologist, Murdoch University, and Andrew Loch, Entomologist with CSIRO, located in the CALM Research Centre in Manjimup. We learned that the Forest Products Commission was originally a part of CALM, but was recently split off into its own department to manage the commercial side of

the forest resource. The Commission maintains the Research Centre, which employs 11 scientists who evaluate wood properties and how industry utilizes the resource.

Terry Jones gave a presentation on the status of the wood products industry for Western Australia. In 1999-2000, there were 397,000 cubic meters (168 million board feet) of timber produced in Western Australia: 221,000 cubic meters (94 million board feet) of hardwood and 176,000 cubic meters (74 million board feet) of softwood. There will probably be a cap of 400,000 cubic meters (169 million board feet) of softwood for a mill in the southern part of the state, although structural softwoods are gradually replacing structural hardwoods. Most of the softwood resource is *P. radiata*, with some *P. pinaster* and *P. maritima*. Besides structural lumber, some other uses for softwoods include medium density fiberboard (150,000 cubic meters [63.6 million board feet] per year), particleboard (150,000 cubic meters [63.6 thousand board feet] per year), and pallets. Although softwoods have been replacing hardwoods for structural wood, there is a concern that *P. radiata* will not be replanted when it is harvested. There is a tendency to replant *P. radiata* sites with faster-growing shorter-rotation hardwoods (e.g., *E. globulus*) for pulp production. Terry Jones felt that planting incentives might be needed in order to avoid a shortfall of sawlog resource in the future. In some low-rainfall sites that do not lend themselves to competitive pulpwood production, there is an effort being made to grow eucalypt sawlogs on a 25- to 30-year rotation. There may also be a veneer plant set up in the northern portion of the state to deal with the dry site *P. pinaster* resource. The state also plans to import sawn lumber from New Zealand and Douglas-fir from California. Some softwood is now being shipped to India in spite of the low supply.

SEPTEMBER 22

We visited the Port of Bunbury and toured a chipping facility operated by WA Plantation Resources. The General Manager of Woodchip Operations, Mr. Ian Telfer, showed us the facility, owned by Marabini, a Japanese trading company that is a major exporter of chips. This port has been exporting chips of marri (*Corymbia calophylla*) and karri (*E. diversicolor*) since 1976. All of the chips sent from here are destined for the Japanese paper market.

SEPTEMBER 23

The team drove from Bunbury to Manjimup.

SEPTEMBER 24

The team met with personnel from Washington Plantation Resources in Manjimup and learned about the plantation resource and associated harvest operations in the area. The team returned to the CALM offices for a closeout session with personnel from Washington Plantation Resources and CALM specialists on what we had seen during the day. We also had an opportunity to examine insect specimens collected by Andrew Loch from *E. globulus* plantations. Dr. Janet Farr provided the names of scientists she had worked with in Japan at the Forest Products Research Institute who have developed a pheromone for *Monochamus* spp. woodborers.

SEPTEMBER 25

In the afternoon, the tour of Western Australia concluded and the team traveled from Manjimup to Perth.

SEPTEMBER 26

The sub-team returned to Canberra.

TASMANIA, SOUTH AUSTRALIA: SEPTEMBER 16–25, 2001

The Tasmania/South Australia sub-team was comprised of Dr. Dennis Haugen, USDA Forest Service Entomologist, Drs. Gregg DeNitto and John Kliejunas, USDA Forest Service Plant Pathologists, and Dr. Ed Podleckis, APHIS Plant Pathologist.

SEPTEMBER 16

We departed Canberra early in the morning for the flight to Hobart, Tasmania. We were met in Hobart by Tim Wardlaw, Forest Pathologist, Forestry Tasmania. Tim and Dr. Humphrey Elliott, Chief of Forest Research and Development, Forestry Tasmania, took us on a tour up Mt. Wellington overlooking Hobart.

SEPTEMBER 17

The morning was spent at the headquarters office of Forestry Tasmania, where we received an overview of Forestry Tasmania and forest industry operations. In addition to Tim and Humphrey, we were greeted by Dr. David de Little, entomologist with Gunns Ltd. Tasmania has a temperate maritime climate. No place on the island is more than 115 km (72 miles) from the water. The main ports are Hobart, Davonport, Burnie, Bell Bay, and Triabunna. The latter three are the ports from which wood chips are exported. The main timber resource in Tasmania is the wet sclerophyll eucalypt forest. The principal species include *Eucalyptus regnans*, *E. delegatensis*, and *E. obliqua.* In addition to native forests, the plantation resource is becoming a more important component. Plantation species include *E. nitens* and *E. globulus*. The species selected for planting depends on elevation and site characteristics.

Forestry Tasmania is now a government-business enterprise that oversees about 1.5 million hectares (3.7 million acres) of multiple use state forestlands and 178,000 hectares (439,848 acres) of forest reserves. Approximately 830,000 hectares (2.1 million acres) are available for wood production. The remainder (about 40 percent of the total) is under some reserve designation (World Heritage, National Park, and other). Currently, there are about 72,000 hectares (178,000 acres) of state forests in plantation, with 50,000 hectares (123,553 acres) of softwoods (mainly *Pinus radiata*) and 22,000 hectares (54,363 acres) of hardwoods. Hardwoods are by far the most common type of plantation being established. Softwood plantations are still being established, but at a much lower rate than eucalypt plantations. About 6,000 hectares (14,826 acres) of plantations are being established each year, mainly through the conversion of native forests and pasture land. Forestry is the second largest employer in Tasmania after mining.

As stated above, Forestry Tasmania manages both natural forests and plantations. The main hardwood plantation species are *E. globulus* (85 percent) and *E. nitens* (15 percent). Forestry Tasmania has begun managing its hardwood plantations for the production of high quality saw logs. They manage on a 20-year rotation. Pruning of the lower 2.8 meters (9.2 feet) is done at about age 3. Only those plantations in good condition and growing at appropriate rates are pruned. About 300 trees/ha are pruned as future crop trees. Trees selected for pruning are based on growth and quality rather than spacing. At age 8 to 10, plantations

are thinned of non-pruned individuals. These trees are sold as pulp logs and for poles. Chips are currently exported primarily to Japan, but also to Indonesia, Korea, and Taiwan. Plantations of *P. radiata* are managed for saw log production with an average rotation age of 25 years. Some new *P. radiata* plantations are being planted by Forestry Tasmania, but at a low rate. Natural forests that are managed are primarily younger forests that regenerated following stand-replacing fires. Logs harvested through commercial thinning from these coupes are classified as regrowth and are considered of higher quality for pulpwood than those from old-growth forests. Native forests are managed on an 80- to 100-year rotation, which can be reduced to 55 years with thinning. When the drier, more open forests are regenerated as natural forests, advanced regeneration is often retained during logging. Clearfalling is still the primary means of harvesting wet eucalypt forests, although research is being conducted on alternatives to clearfalling in wet forests. Seed for regeneration are collected from local trees to maintain local genetic characteristics. Seed of species are pooled to mimic preharvest species composition and proportions.

Approximately 40 percent of the state of Tasmania is in reserve status, mainly in the west. About 17 percent of State Forest land is managed by Forestry Tasmania, and contains both production forests and protection forests (forests where logging is excluded, such as wildlife habitat strips and riparian strips). Private land comprises 39 percent of the forest land in Tasmania. Half of the wood harvested in Tasmania comes from private forest lands, which contain 1,031,000 hectares (2.5 million acres). At maximum development, it is estimated only 5 percent of the State Forest land in Tasmania will be in plantation.

Dr. David de Little presented information on the forest resources and operations of Gunns Ltd., the largest private forest landowner in Tasmania. They are the largest hardwood sawmiller and producer of decorative wood veneer in Australia. The veneer logs are harvested from natural forests and are processed at mills in Boyer and Somerset. They are also the largest exporter of wood chips in Australia. Gunns owns 175,000 hectares (432,434 acres) of freehold land. Most is in the northwest part of the state, but holdings are found scattered throughout. They have 65,000 hectares (160,618 acres) in plantation with 60,000 hectares (148,263 acres) of *E. nitens* and 5,000 hectares (12,355 acres) of *P. radiata*. Gunns is planting about 6,000 hectares (14,826 acres) per year solely of *Eucalyptus*. They produce about 13 million *Eucalyptus* seedlings per year at their nursery in Burnie. Most are planted on their lands, but they do sell to other private forest landowners. They also have a research section, which is involved in *Eucalyptus* genetics research and breeding, forest health surveillance and management, and fiber technology. Gunns has five export chip mills; one at Triabunna, two at Long Reach, one at Hampshire, and one at Bell Bay. These mills produce more than 4.5 million tonnes (= metric ton) per year of *Eucalyptus* chips from both plantations and natural forests. The foreign markets for these mills include Japan, China, Korea, Indonesia, and Taiwan. They have expansion capacity planned of 2.5 metric million tonnes of plantation chips by 2008, a 50 percent increase over current production.

Only limited studies of decay have been done in plantation forests. There is concern about an increased incidence of decay associated with pruning for production of high quality saw logs. In limited surveys on moister sites (above about 1,100 mm [43.3 inches] annual rainfall), a high incidence of decay was associated with

pruned branches, and the larger the branch diameter, the higher the incidence. This work was done on older trees of marginal quality. It is hoped that the incidence of decay will drop with current management of pruning higher quality trees at age 3 years with one lift.

David de Little discussed a complex of insects that preferentially occupy chip piles. These include members of the Staphylinidae, Nitidulidae, and Lathridiidae. Insects in this complex are primarily fungus feeders, but they do lay eggs on the chips. To date they have not resulted in problems for ports in Japan and are remarkably similar to the complex of insects recently described on softwood chips in British Columbia by David Evans.

September 18

On September 18, we met with Dave Robson, Sales and Operations Forester for Forestry Tasmania. The team traveled with Dave and Tim to a native forest-harvesting site managed by Forest Tasmania. Operations were harvesting *E. obliqua*, *E. delegatensis*, and *E. regnans* from the wet sclerophyll forest on a 70- to 80-year rotation.

We traveled to a 15,900-hectare (39,290 acre) LTER (long term ecological site) site at Warra, about 60 km (37 miles) southwest of Hobart. The Warra site, which is a sister site to other LTER sites around the world, was established in 1995 with two objectives: to foster long-term (five or more years) ecological research monitoring, and to facilitate the development and demonstration of sustainable forest practices. The site is managed by a Policy Committee, which includes representatives from Forestry Tasmania, the University of Tasmania, and other agencies.

In the afternoon, we returned to Hobart and visited with Dr. Caroline Mohammed, Forest Pathologist, and some of her students at the University of Tasmania. Dr. Mohammed has a joint appointment with the university and with CSIRO.

We spent the night 8 km (5 miles) south in the coastal town of Orford.

September 19

On the morning of September 19, our group visited a harvest site in dry, east coast sclerophyll forest. We were met by Tony O'Malley, Gunns Ltd. Forester. The land is government-owned and managed by Forestry Tasmania. The primary species being removed included *E. obliqua*, *E. globulus*, and *E. amygdalina*.

In the afternoon we visited two Gunns chip mills near Launceston. These are the Long Reach mills. We were accompanied by Alistair McKendrick, Gunns Ltd., Kevin Jordan, AQIS Quarantine Officer, and Sharon Harrot, AQIS Shipping Officer. We were told that no special endorsements are required on phytosanitary certificates for log and chip exports. AQIS does a visual inspection of chips prior to shipment. They principally look for living insects. They have more concern with the potential entry of any exotic organism from the ships and the loading of chips into ships holds that previously carried other materials, such as grain.

September 20

We traveled to the Gunns Ltd. and Cooperative Research Centre for Sustainable Production Forestry offices in Ridgely. We received a tour of the chip quality-testing laboratory

where all of the chips collected from the five Gunns mills are tested.

We traveled to the port of Burnie from the Hampshire mill. John Barber, Gunns Ltd., met us. Most of the chips at this port (95 percent) come from the Hampshire mill. The remaining chips come from local sawmills. They are tested for quality and added to the appropriate mix. The port site can store 80,000 tonnes of mixed forest chips, 80,000 tonnes of E50, and 60,000 tonnes of E54. Each ship holds 40,000 to 45,000 tonnes. The port loads on average 28 vessels each year. They previously exported pine chips, but have not for the past three years. They have also exported some eucalypt logs from this port, but not regularly. *Pinus radiata* logs are exported from the port to Korea and Japan. These are debarked at the destination port.

We spent the evening at Boat Harbour.

SEPTEMBER 21

We traveled to Wiltshire and viewed a Forestry Tasmania merchandising yard trial with Mike Farrow. The purpose of the yard is to receive, sort, and prepare logs for their maximum value. Only logs that can be sawn or made into veneer are processed. Expert sawyers examine each log to determine the best utilization. They saw logs into the appropriate lengths and remove defective portions. Segments that are defective or too short are sold as firewood. Defective logs are sent to a chip mill. The main product desired is export-quality veneer logs. The aim is to recover veneer (rotary peeled) logs from logs that would traditionally be graded as pulpwood. About one-third of the logs they receive are veneer quality. The other two-thirds is split equally between sawlogs and pulp logs. This trial was started in April 2000 and will close at the end of 2001. This pi-

lot yard processes about 2,000 tonnes per week from State Forest lands. The principal species received is *E. obliqua* coming from coupes up to 40 km (25 miles) away. Different methods of bar coding and labeling are also being tested. Forestry Tasmania is proposing to establish merchandising yards in three areas in the state: near Geeveston, Bell Bay, and Smithton. These are the main areas of plantation development. When an operational yard is established, Forestry Tasmania wants to achieve production of 200,000 tonnes per year.

In the afternoon, we returned to the Burnie port and met with Jeff Angel of Forestry Tasmania to view export logs, both eucalypt and *P. radiata*. Gunns and Rayonier have a joint agreement to ship *P. radiata* logs. The eucalypt logs are exported by Forestry Tasmania. Logs are individually identified with bar codes that contain information on species and volume. Logs are shipped in holds, not in containers. Korea is the main destination for the *P. radiata* logs. There is no debarking requirement by Korea. Logs are fumigated upon arrival in Korea. The primary quarantine issue we observed was that the logs were sitting directly on the soil. Bottom logs with soil are washed prior to loading. Efforts are being made by Forestry Tasmania to get the Port of Burnie to hard surface the yard.

Our last stop of the day was to visit Andy Warner, Private Forests Tasmania (PFT). The primary role of Private Forests Tasmania, a Tasmanian government authority established under the Private Forests Act in 1994, is to promote sustainable native forest management and encourage the expansion of plantations on private land. Andy provides governmental assistance to smaller landowners similar to the U.S. Cooperative Extension Service. About 80 percent of the private forest lands are in small ownership. PFT encourages landowners to

grow high value products on their small areas to obtain acceptable economic returns and provides planning and policy advice. Andy sees increasing opportunities for farmers to enter the export log market. Because of the small volumes private owners have available, a tree growing cooperative, Farmwood, has been formed that combines timber from various owners for sale. Our last evening in Tasmania was spent in Burnie.

SEPTEMBER 22

We flew via Melbourne to Adelaide, and spent the night.

SEPTEMBER 23

The next day we drove approximately 500 km (311 miles) southeast to Mt. Gambier in the lower southeast of South Australia, adjacent to the state of Victoria. We spent the night in Mt. Gambier.

SEPTEMBER 24

We met with Dr. Charlma Phillips, Forest Health Scientist with ForestrySA. ForestrySA, (formerly the Woods & Forests Department) has been privatized, and much of their work is done under contract for industry. They also manage smaller areas for private owners. There is no harvesting of native forests in South Australia. The primary focus of plantation species remains *P. radiat,a* and there is no conversion to *Eucalyptus*. The vast majority of government land is to stay in *P. radiata*, although there are experimental plots of *Eucalyptus*. Plantation *Eucalyptus* is a result of the conversion of pastureland and has increased during the past five years. A major user of *Eucalyptus* chips is Kimberly Clark, which has a pulp mill near Millicent. This mill uses both softwood and hardwood chips for pulp production. Kimberly Clark does not own a *Eucalyptus* resource, but buys timber from ForestrySA and private owners. A rotation of 10 to 13 years is expected, depending on soil condition. A geographic area in southeast South Australia and western Victoria, known as the Green Triangle, is receiving attention for the growing of *Eucalyptus globulus* because of the region's good soils, high rainfall, and mild winters. Investment companies are buying or leasing lands in this area for the production of *Eucalyptus* plantations. ForestrySA and joint venturers (Mitsui Plantation Development Pty. Ltd., Nippon Paper Treefarm Australia Pty. Ltd., and MCA Afforestation Pty. Ltd.) are managing a Green Triangle Tree Farm program for production of plantation *E. globulus* chips for export through the port of Portland. The *E. globulus* plantations will be within a 150 km (93 mile) radius of the port.

We went to a 9-year-old *Eucalyptus* plantation just inside the border of Victoria with Charlma and Peter Lock, Kimberly Clark forester. Kimberly Clark deals mainly with pulp logs to feed their mill. They need 25,000 tonnes/year of *Eucalyptus* chips for the mill. They keep their *Eucalyptus* and *P. radiata* chips separate because of different pulping requirements. Peter expects the pulp mill capacity to be exceeded within several years as the recently planted *Eucalyptus* comes of age. The current exports are all *P. radiata.* About 1 million tonnes are exported annually. Chips go to Japan and roundwood pulp and sawlogs are shipped to Korea. Three companies are in line to export *Eucalyptus* chips to Japan when they become available.

A mechanized harvesting operation was underway in the plantation. A Timbco processor cut, debarked, delimbed, and then cut the trees to length. A forwarder then picked up

the bundles and moved them to the chipper. A chipper processed the logs and blew them into vans for hauling to the mill. This equipment will be changing soon as a smaller feller buncher is used with a skidder, and a flail debarker/delimber at the chip machine will be added. Much of the bark was removed from the logs, but strips sometimes remained attached. When the forwarder picked up the bundles, limbs were incorporated. We saw many logs with a thin layer of soil on them. All of this contamination went into the chipper at the landing. There are four workers per shift on the site plus the truck driver. Working two shifts per day, they harvest an estimated 300 tonnes per day. This plantation will be regenerated through coppicing. When shoots are about 3 to 4 meters (9.8 to 13.1 feet) tall, they will be thinned to two shoots per stump. Since additional sprouts will come up, this thinning is repeated in 1 to 2 years. Plantation trees are not pruned because chips are the product. Even when sawlogs might be the objective, pruning is not done because of decay entry. They estimate that there are three rotations of eucalypts for every one rotation of pine. Even so, pine plantations are not, for the most part, being planted with eucalypts. New eucalypts are being planted on converted pasture, but with the expansion of the wine grape industry, land is at a premium. Kimberly Clark is harvesting about 500 hectares (1,236 acres) per year and 300 tonnes per day to feed their mill. To meet this demand, some 30-year-old *E. regnans* plantations in Victoria are being harvested and chips hauled 600 km (373 miles).

Lock and Phillips were split on their opinions as to whether eucalypt acreage would exceed that of pines, with Lock believing it would and Phillips disagreeing. Interestingly, all of Victoria's state-owned plantations have been sold to a subsidiary of the John Hancock

Insurance Company. The native forests in the area are what is referred to in the rest of Australia as "scrub" forest. They are composed of primarily *E. obliqua* and *E. ovata*. There are also *E. camaldulensis* growing in the paddocks. These native trees are highly protected and, except for rare occasions, cannot be harvested. According to Phillips, the most common diseases found in these plantations include the leaf pathogens in the genera *Mycosphaerella* (especially *M. cryptica*) and *Aulographina*. Because the plantations in the area are still young, decays are relatively uncommon. Phillips believes the low disease incidence is probably also due in part to the low humidity.

We returned to the office and discussed the forest health situation with Charlma. ForestrySA does aerial detection over the *P. radiata* plantations mainly looking for patches of mortality. These are examined by ground crews to determine if sirex woodwasp (*Sirex noctilio*) is present. Other surveys are not routinely performed. ForestrySA provides forest health services on the lands they manage and to larger owners under contract. This includes assessment of insects and pathogens that are observed or submitted for analysis. The focus in *Eucalyptus* is on younger trees up to three years old when growth impacts are most probable. The primary focus is on agents damaging foliage, especially defoliators. All of the insect pests are native to Australia.

SEPTEMBER 25

We drove back to Adelaide (with a stop in Kingston to view the giant lobster), and visited the Waite Campus, University of Adelaide. We met with Dr. Gary Taylor, entomologist and taxonomist of psyllids.

September 26

We flew back to Canberra and rejoined the WIPRAMET group.

CANBERRA: SEPTEMBER 27-28, 2001

The three WIPRAMET sub-teams reassembled in Canberra at the offices of Plant Biosecurity for a closeout session. Each group discussed some of the highlights of things they learned during their state visits. The sub-team that traveled to Queensland and New South Wales (Michael Haverty, Borys Tkacz, and Jessie Micales) made the following observations: termites were swarming in some areas, and logs with termites were seen in some log decks. The team learned that the termite *Coptotermes acinaciformis* was introduced from Australia into New Zealand in logs. Adults of *Hylurgus ligniperda* were seen swarming at a log deck with various species of pines. Some clonal hybrids of pine (*P. caribaea* and *P. elliottii*) are being managed intensively for sawlogs, using herbicides and fertilizers. The newly introduced woodborer *Arhopalus* sp. was also seen on pines.

The other two sub-teams that traveled to Tasmania and South Australia (Dennis Haugen, Gregg DeNitto, John Kliejunas, and Ed Podleckis) and to Victoria and Western Australia (Hal Burdsall, Jane Levy, and Andris Eglitis) also offered some highlights of their state trips.

September 28

The team departed Canberra and returned to the U.S.

APPENDIX B—SUMMARY OF REVIEWERS' COMMENTS AND TEAM'S RESPONSES

INTRODUCTION

A draft of the Australian *Pinus* pest risk assessment was provided to 101 reviewers in various countries, including Australia, Canada, New Zealand, the Union of South Africa, and the United States. Individual reviewers were selected on the basis of their interest and participation in previous pest risk assessments for imported logs and chips, their expertise in specific taxonomic groups of pest organisms, or their knowledge of pests of *Pinus radiata* and other pines.

Responses were received from seven reviewers or organizations (see Acknowledgments for their names and addresses): two from Australia, one from New Zealand, and four from the United States.

The pest risk assessment team read all reviewer responses and, as a group, discussed the comments or concerns of each reviewer. Where deemed appropriate, the team made changes to the document using information derived from the reviewers' comments as well as additional information the team members had developed after distribution of the draft. Comments from reviewers that pertain to specific pests are included at the end of individual pest risk assessments, followed by a brief response from the assessment team.

GENERAL COMMENTS FROM REVIEWERS

In summarizing their general impressions of the draft document, most reviewers were favorably impressed with the quality and comprehensiveness of the draft document. A representative sample of reviewer comments is listed below.

"The authors did a very good job of summarizing the literature and in reviewing the pest status of the scolytids and platypodids." (Bright)

"Overall the Report was complete, well written and addressed thoroughly the scope and objectives of the Assessment. The WIPRA team used the format and methodologies that have been successfully applied to other recent pest risk assessments associated with the importation of unprocessed logs and chips into the US. The visit to Australia by WIPRA members during September 2001 was a critical component of their information gathering task. They spent time with key forest entomologists and pathologists who are familiar with forest health issues in their respective forest/plantation growing regions within in Australia. This Report demonstrates the benefits of the collaborative cooperation between forest health specialists in Australia and the United States." (Stone)

"The chapter on *Pinus* resources of Australia (Chapter 2) is well referenced and a good synopsis of the data available (e.g., data collated by ABARE and NFI for 2005)." (Stone)

"I believe that the list of potential insects and pathogens associated with *Pinus* spp. logs and chips in Australia (Tables 7 and 8) is comprehensive and the eleven groups selected by the team for Individual Pest Risk Assessments are representative of the potential pest organisms that may be introduced with imported unprocessed *Pinus* spp. logs and chips from Australia." (Stone)

"The assessment for entry and establishment in the US and estimated potential economic and environmental impacts of unprocessed logs and woodchips for each of the eleven groups of organisms appear fair and well informed based on the process defined in the risk assessment Guidelines used by the WIPRA team. There is sufficient (international) data available to support the differences in risk potentials proposed for the two commodities, logs and chips (Tables 10, 11 and 12)." (Stone)

"Overall, we were impressed with the document and the WIPRAMET team's foresight in collecting information on both *Pinus* and *Eucalyptus during their trip to Australia in 2000.*" (Oregon Department of Agriculture)

"We would like to commend the authors for including Table 12 in the PRA This type of concise summary is very useful as a quick reference for readers." (Oregon Department of Agriculture)

"I would like...to commend you and your team on the effort taken to consider in a balanced and thorough way the elements of risk presented by these potential pest pathways into the United States." (Ormsby)

MAJOR ISSUES OF REVIEWERS

Other comments from reviewers not pertaining to specific pests were organized into nine major issues. The following section identifies these issues, summarizes specific reviewer comments with respect to each issue, and provides a response to each issue from the Wood Import Pest Risk Assessment and Mitigation Evaluation Team.

ISSUE 1: INADEQUACY OF THE PEST RISK ASSESSMENT PROCESS

Reviewers' Comments

Certain reviewers believed that the pest risk assessment process used in this document was inconsistent, not clear, or not adequate to identify all the potential risks associated with the importation of unprocessed *Pinus* logs or chips.

"Something that we are encountering more and more as regulatory officials is pests with resistant structures or life stages that allow them to survive hostile conditions. Our experience with *Phytophthora ramorum,* among other pests, has made us intimately aware of this phenomenon. Our hope is that future PRAs take this into consideration when assessing risk; not only the plant part that is infested but what life-stage of the plant pest may be infesting it. Also, being on the front lines, we are very aware of how hard it is to detect these pests in incoming shipments and to conduct effective surveys for incipient infestations. The recent introduction of *S. noctilio* and other exotic pests demonstrates these problems." (Oregon Department of Agriculture)

"The statement of purpose includes the identification of the potential pest organisms that may be introduced with imported unprocessed *Pinus* spp. logs and chips from Australia (the baseline for this pest risk assessment is raw, unprocessed logs of Pinus species growing in Australia, with subsequent consideration of the effect of chipping on potential pest organisms). But the document also states 'The objective was to include in the IPRAs representative examples of insects and pathogens found on foliage, on the bark, in the bark, and in the wood.' These two statements

seem contradictory. If the purpose of the PRA is to assess those organisms that are likely to accompany the logs and/or chips, I don't see where assessing foliar pests is relevant, and indeed, could serve to misrepresent the pest risk. The assessment should be limited to quarantine significant organisms that are likely to follow the pathway only." (Zadig)

"Element 1 states 'Pest with host-commodity at origin potential-Likelihood of the plant pest being on, with, or in eucalypt (I assume you meant pine here) logs and/or chips at the time of importation. The affiliation of the pest with the host or commodity, both temporally and spatially, is critical to this element'. It is unclear to me what 'at the time of importation' is. This includes knowing whether or not the logs, including those for chips, have been debarked, i.e., this goes to how one defines 'unprocessed'. This made the draft PRA difficult to review and it seems as though, in reading the IPRAs, that the authors interpreted this element in different ways as well." (Zadig)

"It would be helpful if Element 1 included a criterion that captures the organism's host preferences. In other words, is pine a preferred host or poor host. This is not necessarily made clear in the IPRAs either, but it is an important element of the pest introduction risk. That the organism has capability for large-scale population increases doesn't seem relevant to Element 1." (Zadig)

Response to Comments

When we assess the entry potential of exotic pests, we consider the life stages that could be transported and take into account all of the characteristics they possess that would help them survive transport into a new environment. When these life stages are cryptic,

we assume that they would not be detected and we only base the entry potential on the organism's ability to survive transport.

In our previous pest risk assessments involving unprocessed pine logs, we have found that branches and foliage are sometimes included in log decks in small amounts. These may be epicormic branches or an occasional single branch from a log near the top of the tree. Accordingly, we include for consideration some representative pests that utilize foliage as a substrate even though the primary focus is on organisms on or under the bark and in the wood.

The commodity being evaluated in this pest risk assessment was unprocessed *Pinus* logs and chips, with the presumption that bark would be associated with the commodity. Even after some basic processing (debarking) has occurred, the tolerances for debarked logs allow for a small percentage of the material to contain bark. As such, well-debarked logs could still harbor insects or pathogens that are associated with bark.

The "time of importation" refers to the time period between the loading of the ship and the arrival of the commodity at a U.S. port.

Within the format of the Individual Pest Risk Assessment (IPRA) all of the hosts are listed in order to show the range of plants being utilized by the potential pest organism. We believe it is important to do this in order to appreciate the adaptability that the organism may possess. Usually, the narrative portion of the IPRA discusses the host preferences in greater detail and clarifies if some hosts are only utilized occasionally.

Element 1 includes the criterion of capability of large-scale population increases in order to capture the idea that larger numbers of an organism increase the likelihood that a pest-host association could occur on the commodity.

ISSUE 2: INSUFFICIENT DISCUSSION OF OVERALL PATHWAY RISK

Reviewers' Comments

One reviewer felt that the discussion of the mode of transport of the logs and chips, and the subsequent effect on pest survival and overall risk potential, was not adequately discussed.

"There is little information provided within the risk assessment on the mode of transport most likely to be used to get logs or wood chips from Australia to the U.S., and the likely effect this transport would have on the survival of pests and the overall risk potential. In assuming that the logs and wood chips will be shipped to the U.S. and take more than 10 days to make the journey, no account seems to have been taken of the environmental conditions within the holds of the ships on pest survival.

"Wood chips will begin composting almost immediately after they are first stockpiled, and will continue to compost within the hold of a ship. The temperatures reached during composting can be of a level exceeding current U.S. heat treatment requirements. It would therefore be expected that the effects of composting would significant reduce the risk of any of the pests entering the U.S. on wood chips.

"The atmospheric conditions within ships' holds, namely the low oxygen/high carbon dioxide ratio, would also be expected to reduce to some extent the risk of entry of these pests on wood chips and log shipments, especially on a 10 day journey required for access to the US.

"Both of these factors have been investigated by scientists in the U.S. and other countries and information is readily available in the scientific literature." (Ormsby)

Response to Comments

The effect of transport may have a mitigating effect on the survival of pests in wood chips, logs, and lumber. As described in Chapter 4, large chip piles generate large amounts of heat that favor colonization by thermotolerant or thermophillic microorganisms, even in an open environment with good air exchange. This situation might be exacerbated within the confines of a ship's hold. Micales and Burdsall (2002) determined that wood chips shipped from Chile to the U.S. were colonized primarily by *Trichoderma* and other nonpathogenic "imperfect" fungi and may possibly suppress the growth of sapstain fungi and decay Basidiomycetes. Similar studies have been done by the forest products industry, but these are of a propriety nature and have not been reported in the literature. The Oregon Department of Agriculture, Plant Division, has isolated insects and possible wood decay Basidiomycetes in shipments of lumber from Australia, so we choose to err on the side of caution when factoring shipping conditions into the possibility of transfer.

ISSUE 3: DETERMINATION OF PEST RISK POTENTIALS AND USE OF PEST RISK CRITERIA

Reviewers' Comments

One reviewer pointed out apparent differences in use of the pest risk criteria among authors of the individual pest risk assessments. A second reviewer felt that the relationship between risk values is often oversimplified, resulting in an over-estimation of risk.

"I note some contradictions in the IPRAs which I assume is related to the tendency to be cautious, e.g., a rating of moderate but an assessment of very low risk, unlikely, and extremely unlikely for the pine looper, bark and ambrosia beetles. In some parts of the PRA it seems this discrepancy is due to the selection of criteria, in other areas, it appears to be a decision to exercise caution. In any case, the purpose of a PRA is to predict likelihood, not possibility. This has been clearly reinforced in case law interpreting the WTO's Agreement on the Application of Sanitary and Phytosanitary Measures, the treaty document that describes how risk assessment is to be used to provide scientific justification for phytosanitary measures." (Zadig)

"**Risk values:** The use of risk values in a qualitative risk analysis is common as it allows the assessment of risk of a particular element to be described in a manner that seems to be comparable with other risk elements. Use of a risk matrix based on these risk values is also relatively common internationally, however in my view over simplifies the relationship between the risk values, often resulting in an over-estimation of risk.

"An example of this in the draft risk assessment is provided in the assessment of Sirex Woodwasp (*Sirex noctilio*) (page 69-75 of the draft). In this example the entry potential of Sirex on wood chips is considered 'low' as 'Chips would not be a suitable environment for survival'. As with all of the risk elements, 'low' is the lowest risk value possible. The consequence of introduction of Sirex into the United States is considered 'high', the highest risk value possible under any element. Based on these two assessments the overall risk potential is considered 'low'.

"This risk assessment is also comparable to the three types of termites and the Bark anobid (*Ernobius mollis*).

"What this risk value fails to reflect is that the risk of entry of these organisms on wood chips is less than low; it is highly unlikely or negligible. It may be that those who establish risk mitigating measures for the US will consider a 'low' risk value as falling within an acceptable level of risk for the US, therefore making the distinction seem unnecessary. If they do not however, they may consider a combination of 'low' and 'high' risk likelihoods to mean measures are required when they clearly should not be.

"Compare these examples to the risk values attributed to the Pine Loopers. Once again the risk value allocated for entry potential on both logs and chips is 'low'. However the overall risk rating for logs becomes 'moderate'. It is not clear how organisms that are realistically unable to enter the U.S. on a commodity could be considered a 'moderate' risk regardless of the potential consequences of their introduction. Clearly in this case a 'low' risk value for entry on logs suggests something more than the 'low' risk value for entry on chips. This distinction is not clear within the text of the draft PRA.

The same can be said for the 'low' likelihood of introduction of the bark beetles and 'moderate' consequences of introduction resulting in a 'moderate' pest risk potential rather than a 'low' pest risk potential for wood chips. The risk values themselves do not provide the reader with the justification for why low + moderate = moderate in this case, whereas in others low + moderate = low.

"There would seem to be some value in including a 'negligible' risk value to help the risk assessors distinguish between a low that means 'very unlikely or negligible' from a low that means 'low.'" (Ormsby)

Response to Comments

The team had several discussions during the development of IPRAs to be consistent in the application of criteria used in assessing risk. However, some inconsistencies may remain because each of the pests or pest groups is evaluated in isolation from, not with respect to, the other pest organisms. All high ratings are not equally high in terms of risk. The same is true of the moderate and low ratings. However, if the criteria demand a certain rating and if there is no biological justification for changing it, the rating stands. The author may provide information in his/her discussion of the element that further explains why the rating, although justified by the process, may not be accurate and provide a different estimation of risk. The establishment of risk criteria for each element is designed to minimize biases and provide transparency to enable the reader to determine how a rating was derived. Similarly, the overall pest risk potential is based on an established method to provide consistency between risk assessments (see Table 2). Pest risk is based on probabilities as determined by the assessor, not by likelihood. The process used here in this risk assessment is consistent with

APHIS guidelines and with guidelines adapted by 92 of the IPPC member countries.

Risk values are a continuum, not discrete categories. However, in order to portray risk to readers in a qualitative assessment, some level of categorization is required. The number of categories established is somewhat arbitrary, and we could include more categories to provide a finer breakdown. We do not believe this would provide regulatory agencies any additional information on which to base their decisions. The categories should not be used by themselves, but need to be interpreted along with the narrative explanation that accompanies them. We have adopted three categories in our IPRAs to be consistent with the methodology used by USDA APHIS in their "Guidelines for Pathway-Initiated Pest Risk Assessments" (2000). We rely on USDA APHIS to use the ratings and narrative description to determine if the organism is of sufficient risk to require risk management measures.

Issue 4: Other Types of Potential Pests

Reviewers' Comments

Reviewers expressed a concern that certain organisms that may not be identified as potential pests could be transported on logs and chips and become pests upon arrival in the United States.

"We also recommend adding an IPRA for *Bursaphelenchus* sp. We already have one pine wilt nematode in the US; we don't need another. WIPRAMET should also consider other potential hitchhikers such as mollusks that could impact our ecosystems and agriculture." (Oregon Department of Agriculture)

Response to Comments

We have chosen to concentrate on pests associated with the specific commodities of wood products, including wood chips, logs, and lumber, and have not addressed wider issues associated with general shipping and transport. Incidental hitchhikers have been discussed in previous Pest Risk Assessments (Tkacz et al. 1998, Kliejunas et al. 2003). The issue will be considered by APHIS as part of the overall mitigation requirement, but is beyond the scope of this document. The isolation of *Bursaphelenchus hunanensis* in Australia was confined to several old dying trees (*Pinus radiata* and *Pinus halepensis*) in Melbourne; no plantation trees were affected. These infested trees were eradicated, and subsequent surveys across Australia since 2003 have not detected additional infestations (Dr. Ian Smith, University of Melbourne, pers. comm.; Dr Angus Carnegie, Secretary of the Australian Forest Research Working Group 7 - Forest Health, unpublished data). For this reason, we did not write an IPRA on *Bursaphelenchus*.

ISSUE 5: UNKNOWN (SLEEPER) PESTS

Reviewers' Comments

A concern expressed by one review was that organisms that are not recognized as pests in their country of origin may reach pest status when introduced into a new environment.

"It would be wonderful if WIPRAMET could figure out a way to include an IPRA for the 'great unknown.' Far too often, it is the insect or pathogen that is not a problem in its native territory that wreaks havoc when introduced to a new ecosystem. Perhaps data from past examples such as *P. ramorum* or *Scolytus multistriatus* (and Dutch elm disease) could be used to develop a model to predict the poten-

tial impact of this 'great unknown.' (Oregon Department of Agriculture)

Response to Comment

The assessment team recognizes that the "great unknown" is a major concern when trying to anticipate the impact of an exotic introduction of any type. However, APHIS is required to demonstrate pest risk before being allowed to regulate a commodity. The WIPRAMET approach is to examine representatives of all known organisms that are of concern and their possible modes of entry on logs and chips. Unknown organisms obviously cannot be evaluated. However, the team anticipates that the needs for mitigation of one of that type of organism will be similar for organisms of similar life cycle, thus mitigation for a known organism will be effective for the one that is unknown. In fact, mitigation for a completely unrelated type of pest (e.g., an insect occurring in/under bark) may be effective in mitigating an unknown fungal pest that is found in the same plant part.

ISSUE 6: INTERCEPTION RECORDS

Reviewers' Comments

One review commented on the lack of a discussion on previous interceptions of quarantine organisms in the draft risk assessment.

"Finally, although reference is made to it, no data are presented on previous pest interceptions from Australia on these commodities. ODA has intercepted live *H. ligniperda* on *Pinus* logs that have met the USDA requirements for debarking. We have also intercepted other live Australian insects on raw lumber. These interceptions have been reported in previous letters to USDA-APHIS-PPQ. This information is essential for determining the

actual risk associated with these wood products." (Oregon Department of Agriculture)

Response to Comment

The fact that *Hylurgus ligniperda* has been intercepted in Oregon on "debarked" logs is consistent with its repeated interception in other countries and substantiates the "*High*" rating for "Entry potential" that it received in the exotic bark beetle IPRA for our risk assessment. The team has pursued data on interception records with APHIS and ODA. A discussion of these findings is presented in Chapter 2. We examined the various interception records from Australia and New Zealand and found them to be of limited use in modifying our pest risk assessment.

ISSUE 7: INSECT/FUNGAL ASSOCIATIONS

Reviewers' Comments

One review expressed concern that the potential for insects to carry fungal pathogens was not adequately treated.

"In the southeastern U.S., the exotic ambrosia beetle *Xyleborus glabratus* is the vector of a previously unknown pathogen that causes wilt in red bays. We would also like to see this criterion added to the risk assessment process as a whole." (Oregon Department of Agriculture)

Response to Comment

The team recognizes that the wood boring insects, ambrosia beetles and bark beetles have a critical association with fungi, in some cases as a symbiotic relationship and in other cases as a vector relationship. These relationships have been documented and considered in previous assessments for bark beetles, such as *Hylurgus*

ligniperda in Chilean *Pinus radiata* and for *Chalara australis*, a pathogen causing a wilt disease transmitted by the platypodid ambrosia beetle *Platypus subgranosus*, in Australian eucalypts. The potential for *H. ligniperda* and *Hylastes ater* to be more efficient vectors of the black stain root disease pathogen than the endemic bark beetles in the U.S. is discussed in this risk assessment.

The potential for an organism to be a more efficient vector of a native or introduced pest is one of the rating criteria used for Element 4: Spread Potential.

ISSUE 8: INACCURATE OR INADEQUATE INFORMATION FOR THE PESTS CONSIDERED

Reviewers' Comments

Reviewers pointed out inadequate or incorrect information in the insects and pathogens of concern tables (Tables 8 and 9).

"*Opodiphthera helena* (Lepidoptera) is very specific feeding on *Eucalyptus*. No records of feeding on radiata in the field only mature larvae 'force-feed' on radiata foliage." (Bashford)

"A forest pathologist (e.g., Jack Simpson) would be able to confirm as to whether *Leptographium* occurs in Australian pine plantations." (Stone)

"In tables 8 and 9, the codes are missing or incomplete for several of the organisms listed including *Narycia guildingi, Lasioderma serricorne, Neomerimnetes obstructor, Bursaphelenchus* spp., *Ceratocystis* spp., *Lophodermium canberrianum,* et al.. There is at least one new pest on *Pinus, P. dreschleri,* that needs to be added to the list; others may have been

identified since this list was first compiled as well." (Oregon Department of Agriculure)

Response to Comments

The insect and pathogen tables include all of the organisms of concern that the team could identify on *Pinus* spp. grown in Australia through literature, Australian experts, and other sources up through draft submission to editors in June 2006. Changes and additions were made to tables 8 and 9 based on reviewers' comments to the draft. *Narycia guildingi*, *Lasioderma serricorne*, and *Opodiphthera helena* were dropped from the insect table, and a Category 1 was assigned as the pest category for *Neomerimnetes obstructor.* As *Phytophthora dreschleri* is a native species in the United States, it was not included in the pathogens of concern table.

ISSUE 9: INCLUSION OF CURRENT PEST INFORMATION

Reviewers' Comments

Some reviewers pointed out that the risk assessment was missing recent information.

"A reference source not cited but which may be of interest to the USDA FS WIPRAMET is the 'Annual Pest and Disease Status Report for Australia and New Zealand 2004-2005'. This Report is produced annually by members of the Australian Research Working Group 7 (Forest Health) which is managed by the Research Priorities Standing Committee for the Australian Primary Industries Standing Committee and the Forest Products Committee, and is a comprehensive annual summary of the forest pest and disease conditions throughout Australia and New Zealand." (Stone)

"While we applaud the WIPRAMET team's foresight in their data collection, we are also concerned with the accuracy of information that is now more than 5-yr old. For example, *Phytophthora dreschleri* has recently been identified as a pest in *Pinus* plantations. Have any other new pests been identified since the team's visit and should these be included in the PRA? Has any of the information about the listed pests changed? For instance, *Hylurgus ligniperda* is now found in California and New York and *Sirex noctilio* in five New York counties and in Canada. In addition, the authors refer to *Eucalyptus* repeatedly throughout the document (e.g., p. 4, element #1, sentence #1) instead of to *Pinus*. This can be confusing for readers that are expecting a PRA about the risks associated with *Pinus* commodities. This also indicates that only *Pinus* plantations close to eucalypt plantations were included in the data collection. Accurate and comprehensive information is critical for determining the proper regulations and mitigations measures needed to safely import these commodities into the US," (Oregon Department of Agriculture)

"Lastly, for your information, California and some other states have been performing annual surveys for quarantine pests that may be associated with solid wood packing materials. As a result of these surveys we have found *Hylurgus ligniperda* to be well established here. You may want to contact PPQ to obtain the results of these surveys as these may impact your assessments." (Zadig)

Response to Comments

Though the site visit was conducted in 2001, the PRA is based on current literature and communications with taxonomic and trade experts in Australia and other parts of the world. We have examined the unpublished 2003-2004

and the 2004-2005 "Annual Pest and Disease Status Report for Australia and New Zealand" and found no significant changes in reported pests. We have also obtained interception records from the Oregon Department of Agriculture, Plant Division, that regulates the importation of *Pinus* logs from Australia and interception records from APHIS. This additional information is now described in Chapter 2. The draft PRA was sent to many Australian scientists to review, so any changes in pest status and distribution since our original trip have been noted. Although much of the site visit was concentrated on eucalypt species, pine plantations were also visited in areas not necessarily associated with eucalypt plantings. The team that visited New South Wales and Queensland in particular spent a considerable amount of time visiting plantations planted exclusively to pines with no nearby eucalypt plantings. Incidental references to *Eucalyptus* have been deleted from the text.

OTHER REVIEWER COMMENTS

Reviewers included comments on the draft document and on the risk assessment process in general that provide interesting information, but that are outside the scope of this pest risk assessment. Among these:

"Basically I am opposed to the importation of unprocessed wood products from any country into the U. S. and Canada." (Bright)