Forest health surveillance in Victoria

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Summary

Forest health surveillance (FHS) has been undertaken in Victorian native forests and plantations on an ad hoc basis since the early 1960s in response to incursions and outbreaks of native and introduced insect pests and plant pathogens, such as sirex wood wasp, Monterey pine aphid, *Phytophthora* dieback, phasmatids and other defoliators. The purpose of surveillance is to provide a broad overview of forest health and data for land managers to allow them to take appropriate strategic decisions and manage risks to their estate. Early targeted FHS in Victoria consisted mainly of drive-through surveys with aerial surveillance where required to determine the extent of a particular damaging agent. In 1991, a plot-based surveillance system targeting high-risk sites was developed to monitor levels of *Dothistroma* disease. These plots were used to trigger more intensive surveillance (e.g. aerial) to enable early management intervention once the levels reached predetermined thresholds. In 2001, a broader plot-based monitoring system was implemented for HVP Plantations as part of its risk management program to determine the status, changes and trends in tree health on an annual basis, and provide data for management decisions to control outbreaks threatening the health of plantations. This paper describes the establishment of a plot-based monitoring system, combined with supplementary surveys to provide information on the extent and damage potential of pest agents in the HVP Plantations estate, and its possible application in native forests.

Keywords: forest health; surveillance; methodologies; forest management; plantations; native forests; insect pests; pathogens; diseases; Victoria

Introduction

The forest estate in Victoria

Victoria has the largest plantation area of any state in Australia, with about 191 000 ha under hardwood (predominantly *Eucalyptus globulus*) and 219 000 ha under softwood (predominantly *Pinus radiata*) in 2007 (Fig. 1, Gavran and Parsons 2008). The area of native forest exceeds 8 million ha, of which about 650 000 ha is potentially available for sustainable timber production (Victorian Association of Forest Industries 2008). Native forest is principally managed through the Department of Sustainability and Environment (DSE), Parks Victoria and VicForests. While several companies manage plantations in Victoria, HVP Plantations (formerly Hancock Victoria Plantations) is one of the largest, with 146 000 ha and 19 000 ha of softwood (60%) and hardwood (10%) plantations respectively (HVP 2008) — over 40% of the total plantation resource. The forest health surveillance methodologies described here pertain mainly to these plantations.

Purpose of surveillance

The purpose of forest health surveillance (FHS) in Victoria is to undertake regular and systematic surveillance and monitoring of tree health to provide information on the status, changes and trends in plantation and native forests. It aims to provide a broad overview of forest health and data for land managers to allow them to take appropriate strategic decisions and manage risks to their estate. It also acts as an 'early-warning' system for pest and disease outbreaks, new incursions, and impacts of climatic and edaphic factors (fire, soil fertility, salinity, flooding), all within funding constraints. These surveys are carried out on an annual or biannual basis depending upon the survey requirements.

History of surveillance

Significant — albeit ad hoc — forest health surveillance programs have been undertaken in Victoria since the 1960s in response to incursions and outbreaks of specific native and introduced insects, and plant pathogens, within exotic plantations and native forests.

In native forests, surveillance activities were undertaken in response to specific pest outbreaks and diseases including:

- outbreaks of the native phasmatid *Didymuria violescens* during the 1960s and 1970s in mountain ash (*Eucalyptus regnans*) forests in the Victorian Central Highlands (Neumann *et al.* 1977)
- dieback associated with the exotic soil-borne root or collar pathogen *Phytophthora cinnamomi* to ascertain the causal relationship with native forest dieback in 1969 (Marks and Smith 1991)
- significant defoliation caused by *Aulographina eucalypti* and *Mycosphaerella cryptica* in shining gum (*E. nitens*) on the Errinundra Plateau in the 1970s (Neumann and Marks 1976), and outbreaks of the native psyllid species *Cardiaspina bilobata*, in combination with *A. eucalypti*, on mountain ash in the Central Highlands in the late 1980s–early 1990s (Fig. 2) (Department of Sustainability and Environment, unpublished data).

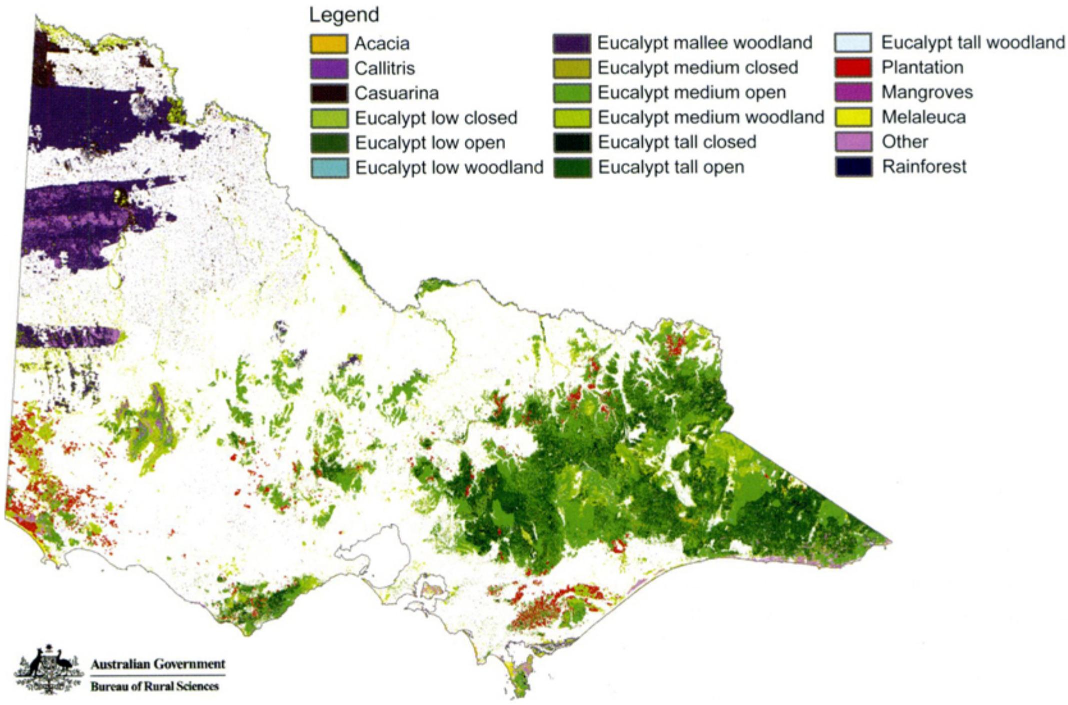

Figure 1. Native forest and plantation estate in Victoria 2005 (Bureau of Rural Sciences 2008)

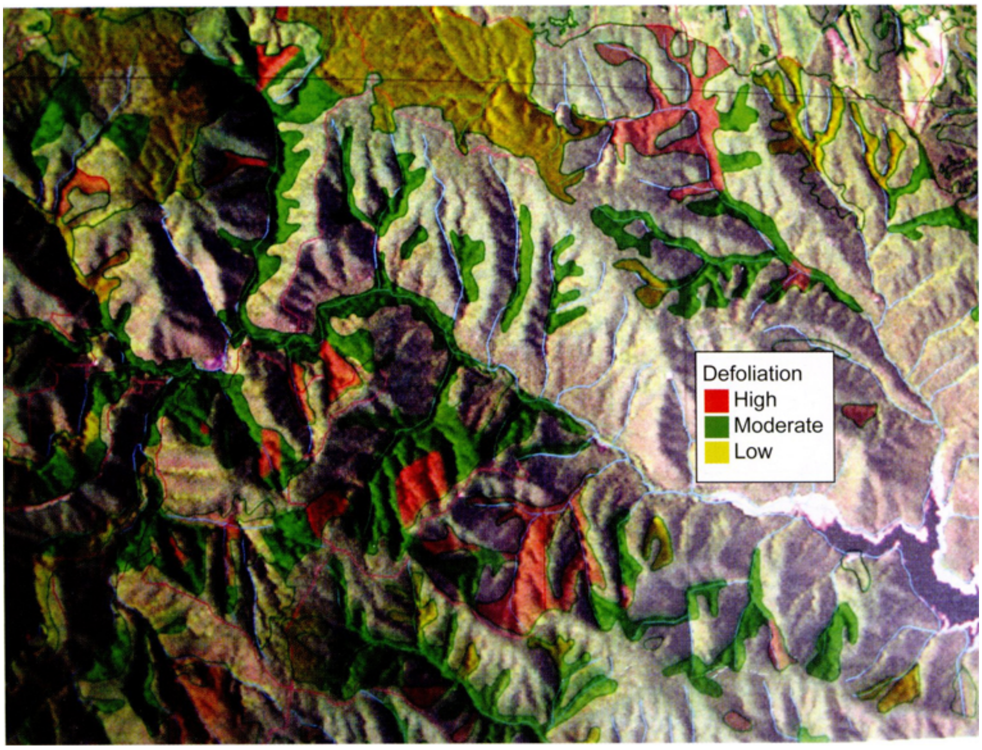

Figure 2. Overlay of a LANDSAT image of aerial mapping of defoliation of mountain ash (*Eucalyptus regnans*) by *Cardiaspina bilobata* and *Aulographina eucalypti* in the Central Highlands of Victoria in 1994 (DSE unpublished data)

These targeted surveillance activities, using a combination of aerial surveillance and ground plots, provided the basis for management action, albeit after growth and overall survival had been affected.

For the softwood industry, response surveillance activities were conducted for:

- sirex wood wasp (*Sirex noctilio*) in *P. radiata* plantations during the 1960s once it was first detected in Victoria (Neumann *et al.* 1987). With the development of a biological control program, surveillance activities for sirex took on an added dimension to provide input into the need and location for the dissemination of the introduced biological control agents (Haugen *et al.* 1990; National Sirex Coordination Committee 2001).

- dothistroma needle blight (*Dothistroma septospora*) to map its spread once it was detected in 1979 (Marks *et al.* 1989). From 1981, targeted surveillance principally consisted of drive-through surveys to map the distribution, severity and extent of the disease as it developed in Victoria. From 1991, a plot-based surveillance system targeting high-risk sites was developed to monitor dothistroma disease levels (Fig. 3). These plots were used to trigger more intensive surveillance (e.g. by air) to enable early management intervention once levels reached predetermined thresholds (I.W. Smith unpublished data).

In 2001 a more generalised plot-based FHS program was developed for HVP Plantations to monitor the status, changes and trends in tree health on an annual basis. As well as providing long-term trends in forest health, it also aimed to provide information for decisions regarding the early management of outbreaks threatening the health of plantations and custodial native forests. A pilot study in state-owned native forest using similar methods commenced in 2007.

Strategy for surveillance

In the USA, forest health monitoring (FHM) is based around a three-phase monitoring system: detection, evaluation and intensive site monitoring (USDA-FS 2003; Bennett and Tkacz 2008). Detection monitoring uses both aerial surveys and ground-based plots to evaluate the status and change in condition of forest ecosystems; then evaluation monitoring determines the extent, severity and causes of any undesirable change detected. The intensive site monitoring aims to provide information on relationships between the causes and effects, and assess specific issues raised in the other monitoring phases (USDA-FS 2003; Bennett and Tkacz 2008).

The underlying strategy for the Victorian FHS system is based on a simplified USDA model, entailing the establishment and monitoring of a series of permanent plots distributed throughout the forest estate, the main factors determining spatial distribution being age class and size of coupe. In these plots a variety of health factors including insect pests, pathogens, nutritional imbalances, animal browsing, weed infestation and abiotic factors are monitored on an annual or biannual basis to match seasonal pest occurrence. A proportion of these plots are also established in areas judged — on the basis of their history and previous ad hoc survey information — to be at high risk of occurrence of specific insect pest and disease problems (e.g. dothistroma needle blight and sirex wood wasp). Where possible, plots are also linked to existing networks of permanent resource assessment plots to correlate health with growth. The Victorian program consists of an annual plot monitoring system similar to the USDA-FS FHM program (Smith and Mangold 1998; Busing *et al.* 1999).

These plot-based surveys are supplemented with other survey methods in response to observations made both during the surveillance (e.g. while driving between plots), and or by forest operation staff during normal operations. Observations made in the plots are used as a trigger for more extensive delineating surveillance including aerial reconnaissance, and subsequently management action is taken where required. Supplementary surveys use roadside drive-through, plantation establishment, diagnostic and aerial methods that will be described in more detail later in this account.

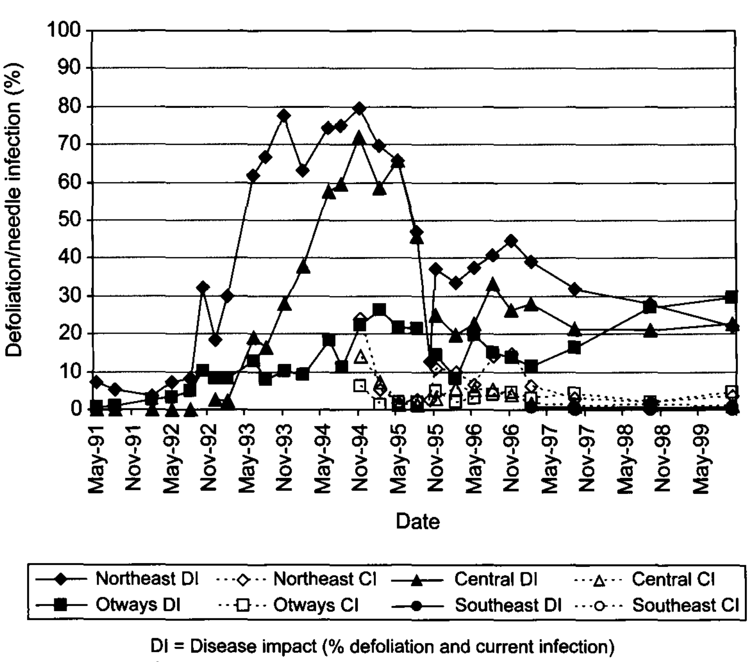

Figure 3. Average *Dothistroma* needle blight infection in disease-monitoring plots established in radiata pine plantations in Victoria from 1991 to 2000

Components of the HVP FHS system

Permanent plot network (PPN)

The main component of the FHS program in softwood and hardwood plantations is a series of 480 permanent health surveillance plots, consisting of twenty trees each, distributed throughout the HVP Plantation estate (one plot every 360 ha) (Fig. 4). Of these plots, 120 (25%) are measured each year, including 40 plots from the previous year's survey to provide continuity between annual measurements.

Placement of plots is important and is dependent upon the age class of the trees and topography of the landscape. Health surveillance plots are grouped into five-year age classes: 1–5, 6–10, 11–15, 16–20, 21–25, 31–35, 35+ y. Within each plantation plots are assigned to different age classes according to the proportion of area each age class represents. The plots are also sited to ensure relatively uniform spatial distribution across the geography of the estate. Plot distribution is initially undertaken on maps generated using GPS (global positioning system) Pathfinder Office version 4 and ArcMap version 9.2, with each new plot assigned a latitude and longitude before leaving the office. The location for each plot is downloaded into a Hewlett Packard iPAQ handheld PC and tablet PC running ArcPad version 7.2. A Trimble Pro XRS differential GPS connected to the tablet provides

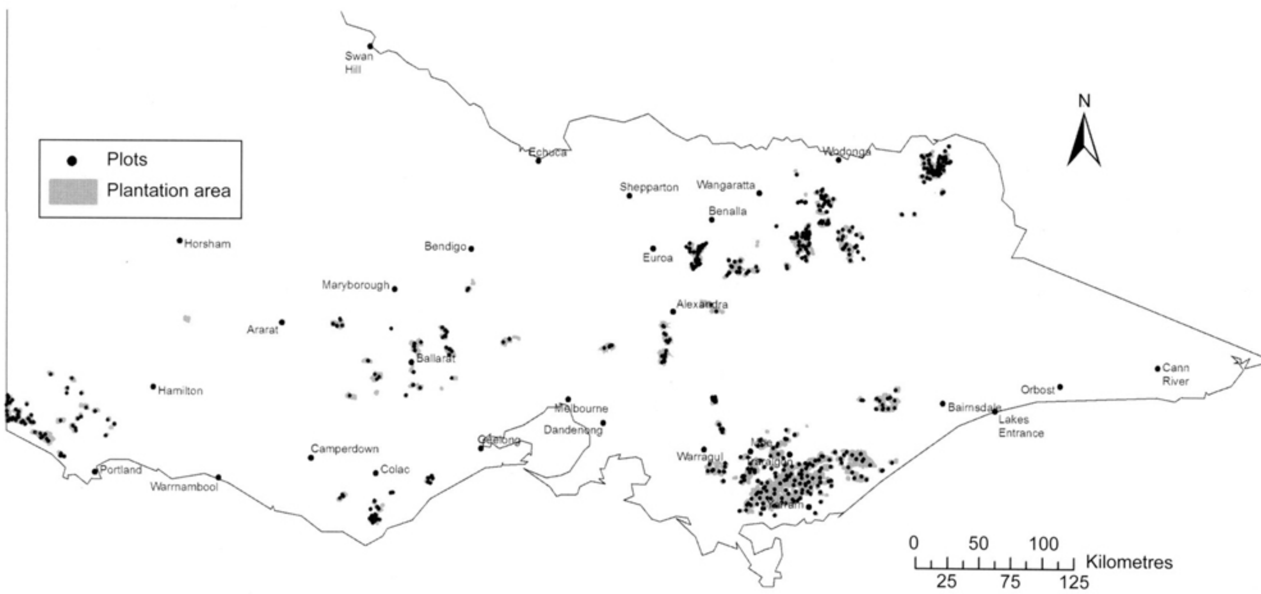

Figure 4. Distribution of 480 permanent monitoring plots across the HVP Plantations estate

real-time directions to locate a road-point closest to each plot. While previously the iPAQ was used in combination with paper maps to determine locations, the tablet provides much improved efficiency for visual navigation. After the road-point is located, the GPS is connected to the iPAQ running TerraSync version 3.01 to find the location of the plot within the plantation. Local on-site factors including ease of access and uniformity issues are also considered when determining the final plot position.

Assessment procedure

After arriving at a plot, a more precise GPS reading is taken at the first tree in the plot. Twenty trees in two rows of ten are then assigned a number from 1 to 20, marked with paint and assessed for their health status. A digital image of each plot is taken at set photo points at each assessment to aid in evaluating change over time.

Health assessment criteria

The presence of insect pests and plant pathogens and the damage caused, nutritional imbalance symptoms, animal browsing, weed infestations and impacts of abiotic factors including fire, drought and other storm-related events (e.g. lightning) are assessed and recorded on the iPAQ using a menu-driven program developed with Visual CE software. Hardcopy data sheets are also carried as backup. Damaging agents are identified and specimens and or samples collected and taken back to the laboratory for further analysis or identification if required. Soil samples are routinely collected at all sites to test for soil pathogens (e.g. *Phytophthora cinnamomi*), and additional site and stand information including canopy closure, species, age-class, aspect and or silvicultural history (e.g. thinning or pruning) is noted. This information provides data to the surveyor on likely pests and pathogens that may be present: for example, in a young (1–5 y age class) *P. radiata* stand in a valley that is reaching canopy closure, needle blight pathogens such as *Dothistroma* should be considered. Finally each tree is assessed using three main criteria: tree status, condition of the unsuppressed green crown, and stem and branch condition (Table 1).

'Tree status' records the overall condition of the tree (living or dead) and its dominance within a stand (dominant, co-dominant or suppressed). It provides a measure of mortality and the tree's position in the stand which may lead to other health issues: for example, a suppressed tree may become more susceptible to sirex attack. 'Crown condition' provides information on the presence of defoliating agents (Fig. 5) and or nutritional issues. The proportion of foliage present (i.e. foliage retention), and the proportion of foliage discoloured (e.g. yellow or brown), is assessed in classes of 10% for the upper and lower crown separately. The position of symptoms in the crown provides an indication as to possible pest agents with, for example, top-down defoliation indicating the presence of Monterey pine aphid, and bottom-up damage cyclaneusma needle cast. 'Stem and branch condition' provides information on possible agents such as diplodia canker (*Diplodia pinea*), and also information regarding tree form which may influence future wood yields.

Upon return to the office, the data and digital images are transferred into a customised Microsoft Access database for data storage, analysis and presentation. Handheld PCs increase the efficiency of data recording and data entry processes, and reduce transcription errors.

Supplementary surveys

The FHS currently undertaken in Victoria has a further five components to supplement the annual monitoring of the FHS PPN. These components were established to:

- take advantage of other observations made by the surveillance team and by operational staff in the performance of their work
- target surveillance of specific biotic agents
- follow up potential outbreaks to establish their extent and the need for management action.

Table 1. Criteria and attributes used in health assessment of forest health surveillance plots in Victoria

Health assessment criteria	Attribute
Tree status	• Tree condition (living, dead < 1 y, dead > 1 y) • Dominance (dominant, co-dominant, suppressed)
Crown condition (Upper 50% and lower 50% of the unsuppressed green crown assessed separately)	• Foliage present (10% increments, 100% being a fully foliated tree) • Foliage type (adult, transitional or juvenile) • Cause of foliage loss (damaging agent) • Discoloured foliage (10% increments, 0 being no discolouration) • Colour of foliage (necrotic, chlorotic, purple) • Distribution of discoloured tissue (edges, interveinal, spots, etc.) • Cause of discolouration (damaging agent)
Stem and or branch condition	• Part of tree affected (stem, branch, etc.) • Location of damage (base, middle, top, etc.) • Layer of tree affected (bark, sapwood, heartwood, etc.) • Type of damage (scar, decay, etc.) • Cause of damage
Other	Additional information regarding potential threatening processes such as weed invasion, animal browsing and abiotic factors is also recorded.

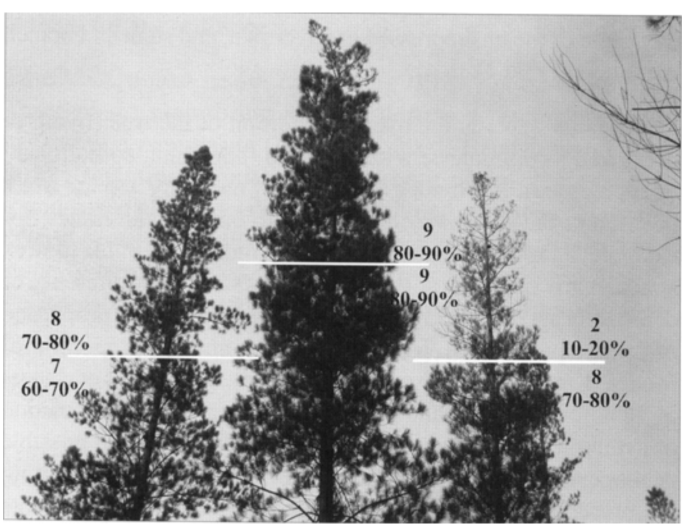

Figure 5. Example of the assessment of defoliation of the upper and lower sections of the unsuppressed green crowns of *Pinus radiata* used for FHS in Victoria (the assessment is of crown retention, such that a score of 10–20% indicates 90–80% defoliation)

Roadside or drive-through surveillance

Roadside or drive-through surveys are conducted during the FHS PPN operation. The FHS officer plans a route through a plantation, to and from a permanent plot, which takes the observer through a range of age classes. Any abnormal stand conditions are recorded and the location mapped. If extensive, a temporary health surveillance plot may be established to record the presence of the damage and its cause so as to allow future monitoring. Roadside or drive-through surveys provide information on the potential extent of an outbreak, and can trigger more extensive surveillance operations (e.g. from aircraft).

Targeted surveillance

Targeted surveys, or pest-specific surveys, are undertaken to monitor development of known pathogens or pests. In surveys of this type, a proportion of plots within the PPN are selected that match the age class and site-specific factors that favour particular damaging agents. An example is dothistroma needle blight surveys that are undertaken in early spring. In these surveys, historic data on outbreaks are used to categorise and initially locate PPN plots in high-risk areas, which are then surveyed annually in early September to evaluate levels of disease. If average plot disease levels in an area rise above a trigger point (in this case 30% infection), other surveillance (such as roadside surveys or, if extensive, aerial surveys) is undertaken to further map the extent and severity of the outbreak, and to determine whether the disease requires management (i.e. spraying). This surveillance is also useful to target areas for future planting of *Dothistroma*-resistant stock at re-establishment.

Establishment surveys

Establishment surveys, generally conducted by plantation staff responsible for the area planted and undertaken six months after planting, are important to check survival and determine any requirement for replanting in the following winter. These surveys can also be used to note any other factors affecting plant health and condition, such as damage by grasshoppers, browsing or shoot die-back and mortality that indicate the need for follow-up diagnostic surveys.

Diagnostic surveys

Diagnostic surveys are carried out in response to observations that point to a potential decline in health or abnormal condition of forests identified during establishment surveys, observations by operational staff in the performance of their work, or reports from the general public. These surveys generally target localised areas of damage for the purpose of collecting material and supplementary information to diagnose a problem.

Aerial surveillance

While annual aerial surveys have been carried out by operational staff in some HVP Plantations to identify management problems (e.g. sirex, nutrition), extensive aerial surveillance is generally carried out only in response to major tree health issues identified through other surveillance. Flights are normally carried out at around 600 m in a fixed-wing aircraft, although helicopter surveillance is preferred when available. Information is sketched onto plantation maps during the survey (sketchmapping). Aerial surveys are carried out to provide information on the extent of a health issue and delimit the areas that may require management action. If necessary, this is followed up by further ground-truthing or problem diagnosis (diagnostic surveys) in response to reports of abnormal stand conditions. Aerial surveillance necessitated by pests or disease outbreaks was carried out in the early 1990s in response to *Dothistroma* outbreaks, and more recently in 2005 to assess Monterey pine aphid damage.

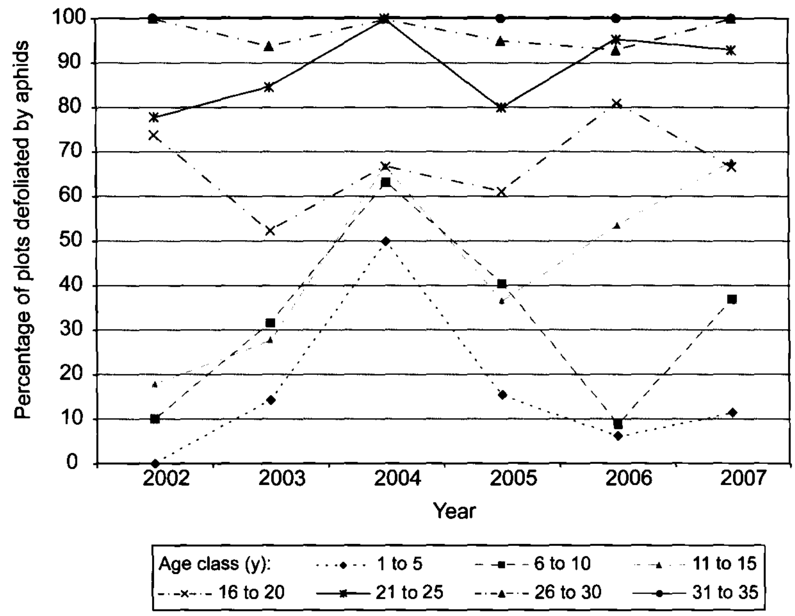

Figure 6. Forest health surveillance data used to show changes in distribution of Monterey pine aphid (*Essigella californica*), across age classes of *Pinus radiata* plantations in Victoria from 2002 to 2007

Reporting

Pest and disease outbreaks recorded during assessments are immediately reported to plantation managers. Following analysis, the data and images in the Access database are made available in electronic form for each region or area. The menu-driven database can be interrogated by a manager to examine the current and past status of an area covered by the plots and to generate a summary report for each plot as required. A summary report for the year is also produced detailing any management issues and the long-term trends in the data.

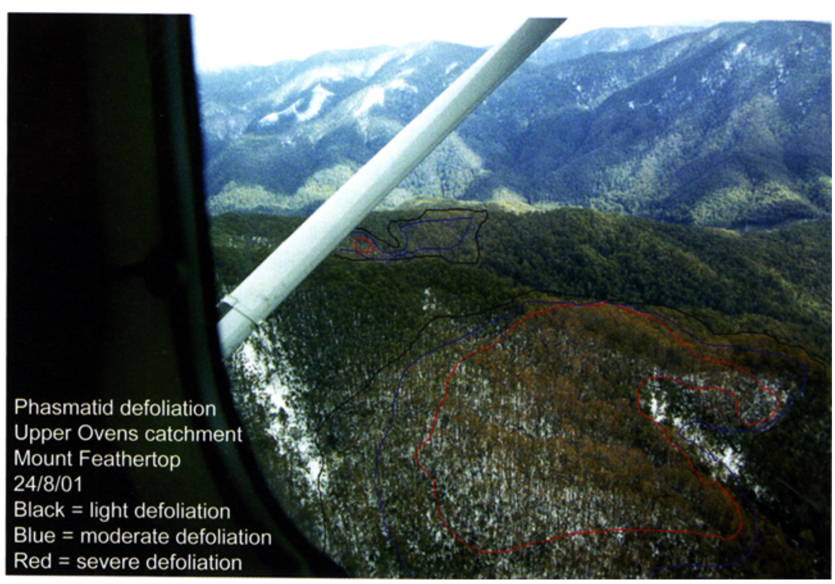

Figure 7. Aerial mapping of phasmatid defoliation of alpine ash (*Eucalyptus delegatensis*) in north-eastern Victoria in 2001 (Image: Mike McCormick, DSE 2001)

Example of results from permanent plot monitoring

The Monterey pine aphid (*Essigella californica*) was first detected in Australia in 1998 and spread rapidly into Victoria (May 2004). The aphid has caused defoliation of *P. radiata* with significant potential growth losses (Smith *et al.* 2000; May and Carlyle 2003; Hopmans *et al.* 2008). The permanent monitoring plots established in 2001 have provided data on the effect of *E. californica* over time (Fig. 6). They show that the impact is primarily on plantations above 16 y of age, although younger age classes are affected in some years. These data highlight to managers the potential effect of the aphid on growth and productivity, and the need to develop management strategies for this significant pest in Victoria. This is an example of the use of FHS to provide data on changes and trends in insect pests and pathogens and to provide information for managers.

FHS in native forests

FHS in native forests is currently based on a mix of ground-based targeted plots and aerial surveys that are undertaken on an ad hoc or response basis to requests following outbreaks of specific pests and pathogens. Targeted ground-based survey plots consisting of between 10 and 50 trees each have now been established for phasmatids (*D. violescens*) (12 plots), chrysomelid leaf beetles (*Chrysophtharta* spp. and *Paropsis* spp.) (6 plots), gum leaf skeletoniser (*Uraba lugens*) or cup moth (*Doratifera vulnerans*) (10 plots), myrtle wilt (*Chalara australis*) (10 plots) and psyllids or *Aulographina* (*Cardiaspina bilobata* or *Aulographina eucalypti*) (10 plots). These plots are assessed either annually or biannually at times of the year that coincide with maximum damage caused by the insects or pathogens. Plots are established in several different forest types across Victoria. Aerial surveys have also been carried out in the past to identify the distribution of larger outbreaks of pests and diseases so that management action can be accurately coordinated (Fig. 7).

Experience of the PPN in HVP Plantations suggests that a similar system could be developed for native forests. A pilot study of a permanent plot-based system, similar to that developed for the plantation industry, commenced in 2007 to evaluate its potential as a long-term monitoring system in *E. regnans* forests of the Victorian Central Highlands.

Discussion

The main purpose of FHS in plantations is to assist in maintaining stand productivity, as biotic and abiotic agents can damage the health of trees and hence the rate at which they grow and produce wood. Regular and systematic surveillance and monitoring of tree health facilitates early detection of damaging agents and thus early intervention to protect investments. FHS also provides information on the status, changes and trends in plantation health that is useful for long-term management. The collated data from surveillance also help over time to build profiles of damaging agents in an area, and enables threshold levels to be chosen on which to base control measures if the latter are available. As well as gathering productivity information, FHS in native forests provides data on ecological diversity and thus helps to monitor very broadly defined 'forest health' (Innes and Karnosky 2001).

Access to markets for forest products is also becoming increasingly dependent upon many elements to demonstrate sustainable forest management. The status of forest health and vitality is recognised as an important criterion under the Montreal Process of Criteria and Indicators of sustainable forest management adopted by Australia (Department of Agriculture, Fisheries and Forestry 2008). It also forms part of the framework of principles and criteria for international accreditation of sustainable management of forests (Department of Primary Industries and Energy 1998; Australian Forestry Standard 2007; Forest Stewardship Council 2008). FHS provides quantitative indicators of the health status of forest areas that can at least partly satisfy such criteria (Carnegie *et al.* 2005; Australian Forestry Standard 2007).

Ideally FHS should encompass all aspects of surveillance and include remote, aerial and plot-based systems as in FHS in the USA (Bennett and Tkacz 2008). With limited funding, a mixture of a plot-based system coupled with targeted aerial surveillance now appears to be providing a useful base level of health monitoring for HVP Plantations in Victoria. To apply a level of surveillance similar to that currently used in HVP Plantations to the 8 000 000 ha of native forests in Victoria, however, would require over 20 000 plots of which 5000 would be monitored on an annual basis. Due to the greater investment in establishing and managing plantations, more intensive forest health monitoring (i.e. more plots) may be expected in plantations than in native forest.

Further development of remote sensing techniques will aid the rapid monitoring of large areas of forest. This is the subject of current research, particularly within Program 1 (Managing and monitoring for growth and health) of the Cooperative Research Centre for Forestry (CRC 2008). The complex nature of native forest, however, means that surveillance based on aerial and remote methods alone cannot provide the detailed data needed for management, and it needs to be supplemented with an on-ground plot-based system. The US FHM/NFI program has 8000 sub-plots, each sampling 38 850 ha, and each is assessed or measured once every 5–10 y (Bennett and Tkacz 2008). Only 200 plots would be needed to sample Victorian native forests at a similar level. Thus a US-style surveillance system would be feasible in native forests in Victoria, providing that the complementary remote and aerial surveillance was also undertaken.

The development of a forest health surveillance system in Victorian plantations and native forests is an important part of understanding and managing the economic and environmental risks associated with forest health. There is a need for land management agencies to recognise these risks and place greater emphasis on the monitoring of forests, and to provide appropriate resources.

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