Forest health surveillance in Western Australia: a summary of major activities from 1997 to 2006

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Summary

In Western Australia (WA), no formal forest health surveillance program is in place, but individual programs within the Department of Environment and Conservation undertake surveys to monitor major pathogens and pests associated with native jarrah and karri forest. Recently the Tuart Health Research Group and the Wandoo Recovery Group were established to undertake monitoring and to coordinate research into the cause of tuart and wandoo decline. For blue gum plantations, Murdoch University has an extensive pathogen research program and private industry has an Integrated Pest Management program to undertake pest surveillance. The Forest Products Commission carries out regular surveys for sirex wasp in pine plantations. Not all the results of surveillance and associated forest health research in WA are formally reported, but they are compiled and evaluated annually and presented in the *Annual Pest and Disease Status Report for Australia and New Zealand* by Research Working Group 7 (Forest Health).

Keywords: forest health; surveillance; native forest; plantations; fungal diseases; insect pests; *Pinus*; *Eucalyptus*; Western Australia

Introduction

In the south-west of Western Australia (WA), the Department of Environment and Conservation (DEC) is responsible for the management of 2.2 million ha of native eucalypt forest and woodland (Conservation Commission of Western Australia 2004). A total of 377 598 ha of plantation consisting of 257 993 ha of blue gum (*Eucalyptus globulus*) and 104 480 ha of radiata pine (*Pinus radiata*) and maritime pine (*P. pinaster*) plantation are managed by private industry (72%) and government agencies (Parsons *et al.* 2006).

Forest health is important for economic, social and environmental sustainability. With uncertainty as to how climate change will affect forest health and biodiversity, knowledge about changes in both native and plantation forest health and the status of native and exotic pests and pathogens is becoming increasingly important. In recent years a noticeable decline in forest, woodland and rural tree health in WA has been a major concern, and forest health has become an important community issue. A public Wood Decline Symposium held in Mandurah in November 2006 attracted more than 260 attendees, including many from concerned community groups and private industry.

At present no formal forest health surveillance program operates in WA and pest and disease survey is mostly undertaken in an ad hoc fashion, usually following opportunistic reports or in association with research projects. Notable exceptions are programs for surveillance and mapping of dieback in jarrah (*E. marginata*) forest by DEC, armillaria root disease survey and monitoring in karri (*E. diversicolor*) regrowth forest by DEC and the Forest Products Commission (FPC), surveillance of sirex wasp by FPC and European house borer (EHB) by the EHB response group in pine plantations, and general pest surveillance in blue gum plantations by private industry. Results of these surveys are reported through various avenues including published research articles, unpublished theses, internal reports, annual reports, information bulletins, guides and web sites. This paper summarises major activities in forest health surveillance and monitoring in WA over ten years from 1997 to 2006. Results from earlier surveys are included where they are relevant to current survey or research. A proposal for a formal forest health and vitality surveillance program for native forest, to be initiated by DEC within the next 5 y, is outlined.

Forest health surveillance and monitoring in native forest

Dieback in jarrah forest

Dieback caused by *Phytophthora cinnamomi* has had a significant effect on most ecosystems in the south-west of WA. The Department of Conservation and Land Management (CALM) and DEC[1] have undertaken surveillance and mapping of *Phytophthora cinnamomi* and its impact since 1978. Survey and mapping is closely associated with both conservation and timber management objectives, and is carried out by trained dieback interpreters within the Forest Management Branch. Dead and dying susceptible plant species are used to map disease fronts (Fig. 1), and soil and plant samples are collected and tested to verify the presence of the pathogen. Aerial photographs are used by an interpreter to detect and locate recent plant deaths, which are then checked in the field. When aerial photographs are not available the area

[1] In June 2006, CALM and the Department of Environment were amalgamated to form DEC. This paper deals with the period 1997–2006 and where appropriate CALM will be referred to rather than the more recent DEC.

in question is intensively surveyed on foot using transects up to 50 m apart (Strelein *et al.* 2006).

From 1997 to 2006 almost 458 000 ha of state forest and conservation lands were intensively surveyed and mapped for the presence of *P. cinnamomi*. Almost 100 000 ha of previously mapped jarrah forest were also rechecked for further spread (Table 1). To facilitate disease mapping, about 107 000 ha of state forest and conservation lands were aerially photographed and around 15 660 soil samples tested for *Phytophthora* spp. Other known species of *Phytophthora* identified from soil samples include *P. citricola*, *P. cryptogea*, *P. megasperma*, *P. nicotianae* and *P. inundata*.

Results of survey and mapping are used to determine protectable areas and to specify hygiene requirements associated with soil movement during management activities. By rechecking previously mapped forest, disease extension was measured (Strelein *et al.* 2006), allowing future spread and impact of disease to be predicted. Since 1978, a total of 720 000 ha of land in the south-west had been intensively surveyed and mapped, and 170 000 ha were found to be affected by *P. cinnamomi* (DEC 2006).

Armillaria root disease

Surveys associated with research prior to 1997 showed that *Armillaria luteobubalina*, the causal agent of armillaria root disease (ARD), had a widespread but discontinuous distribution in karri (Pearce *et al.* 1986) and jarrah (Shearer and Tippett 1988) forest, and in wandoo (*E. wandoo*) woodland (Shearer *et al.* 1997). No further survey or monitoring of ARD has been undertaken in jarrah forest or wandoo woodland, but survey and monitoring in karri regrowth forest is ongoing.

From 1995–1997, surveys for the presence of *A. luteobubalina* were undertaken by CALM to assist in planning thinning operations in regrowth karri stands. Infection points were located using strip-line surveys that were carried out during the *Armillaria* fruiting season from May to July each year. Evidence of the presence of *Armillaria* was based on the sightings of fruiting bodies and or scaring at the base of infected trees, and characteristic white rot at the base of dead trees within disease centres (Robinson *et al.* 1998). Twenty-nine forest blocks, in areas of regrowth considered at risk from *A. luteobubalina*, were surveyed (Table 2). A total of 1500 ha of forest were surveyed of which 502 ha were shown to have ARD present. Disease distribution maps for each forest block were produced and used as a guide to possibly exclude thinning in infected forest areas.

Intensive survey of above- and below-ground symptoms of ARD carried out in 1997–1998, in 25–30-y-old karri regrowth forest in Warren and Dombakup forest blocks, showed that on average 40–45% of trees were infected with *A. luteobubalina* (Robinson *et al.* 2003).

In 2003, stump pulling following first thinning was trialled in karri regrowth as a control measure for ARD. From 2003–2005 *Armillaria* surveys were conducted by FPC following thinning of high-quality karri south of Pemberton. Infection points were located in thinned regrowth forest using strip line surveys based on symptoms of scars on residual trees (Fig. 2) and rot and scars on stumps caused by *A. luteobubalina*. A total of 1010 ha of thinned forest were surveyed and 388 ha were found to have ARD present. Maps showing distribution of disease centres were produced and used to guide stump-pulling operations in infested areas. A number of plots have been established in stands that have undergone stump-pulling treatment in order to monitor the response of the disease to treatment.

The incidence, impact and spread of ARD have been monitored for more than 20 y in a silvicultural thinning experiment south of Pemberton. The trial was established in 1972 karri regrowth by CALM in 1984. Results of monitoring have been used to determine the impact of thinning on the spread and intensity of ARD (Robinson 2003), the impact of ARD on growth and yield (Robinson 2005) and strategies for disease control in karri regrowth.

Table 1. Area of native forest surveyed and mapped by CALM for the presence of *Phytophthora cinnamomi* (Source: CALM Annual Reports 1997–2006)

Year	Area mapped[A] (ha)	Area rechecked[B] (ha)	Other area mapped[C] (ha)	Total area mapped (ha)	Area aerially photographed to assist interpretation (ha)	Soil samples tested for Pc
1996–1997	35 110	7 700	7 640	50 450		1 932
1997–1998	34 007	1 320	11 646	46 973	46 800	2 202
1998–1999	54 298	14 025	7 791	76 114	22 900	2 112
1999–2000	32 844	9 501	6 266	48 611	20 825	1 620
2000–2001	49 270	7 400	183	56 853	10 213	1 462
2001–2002	27 440	8 960	3 420	39 820	1 780	1 155
2002–2003	19 410	8 300	2 090	29 800	4 500	1 205
2003–2004	16 923	17 301	5 320	39 553		1 251
2004–2005	17 505	13 221	5 156	35 882		1 250
2005–2006	12 717	11 969	9 078	33 764		1 475
Total	299 524	99 706	58 590	457 820	107 018	15 664

[A]Area mapped to assist road planning and harvest operations for the FPC
[B]Previously mapped area that was rechecked for further spread
[C]Area mapped for external agencies (mining etc.) and other DEC activities

Table 2. Forest block and area surveyed by CALM for *A. luteobubalina* and ARD in karri regrowth forest in 1996 and 1997 (Source: CALM – ARD survey maps; Robinson and Rayner 1998)

Forest block and compartment number	Regrowth year	Area surveyed (ha)	Area buffered (ha)	Area outside buffers (ha)
Babbington 1	1969	193	117	76
Babbington 1	1974	45	9	36
Babbington 4	1974	16	7	9
Boorara 1	1969	20	0.6	19.4
Boorara 13	1969	81	3.4	77.6
Brockman 12	Mature	45	45	0
Collins 14	1966	8.3	0.4	7.9
Crowea 1	1969	70	3.9	66.1
Crowea 4	1969	22	0	22
Crowea 6	1967	110	20.2	89.8
Dombakup 3	1969	103	32	71
Dombakup 4	1969	78.9	4	74.9
Dombakup 7	1969	16.8	0.2	16.6
Dombakup 7	1971	20	7	13
Dombakup 8	1969	26	7.4	18.6
Dombakup 9	1969	49	35	14
Dombakup 16	1969	12.7	12.7	0
Gray 2	1967	9	0	9
Mattaband 3	1964	82	0.5	81.5
Muirillup 12	1969	31.7	0.7	31
Muirillup 16	1969	80	44	36
Poole 2	1965	17	0.2	16.8
Poole 3[A]	1968	111.4	111	0.4
Poole 11	1968	107.9	4.2	103.7
Poole 13	1969	52	4	48
Warren 2	1972	52.6	20.6	32
Warren 4	1972	18.6	5.6	13
Warren 5	1972	21.7	6.7	15
Total		1500.6	502.3	998.3

[A]Survey results are questionable due to impediments to surveying such as thickness of understorey vegetation, logging debris and litter layer. The survey was abandoned after three-quarters of the coupe was surveyed.

Incipient rot in karri regrowth

A survey conducted in six 12–14-y-old karri regrowth stands in the early 1990s showed that incipient rot and rot occurred in 83% of dominant and co-dominant trees and 28% of subdominant and suppressed trees (Hewett and Davison 1995). Incipient rot was most frequently associated with branch stubs, but was also associated with insect galleries. In billets excised from affected trees, the mean total surface area affected by discoloration, incipient rot and rot ranged from 2% to 5.8% (Hewett and Davison 1995). The fastest-growing trees were those most likely to be infected. The fungi most commonly isolated were *Stereum hirsutum* and *Hymenocheate semistupposum* (Davison and Tay 2008). No further forest surveys were conducted, but sawmill surveys showed that incipient rot and rot were significantly greater in sawlogs from regrowth stands than in those from mature stands (Donnelly and Davison 2008).

Insect pests in jarrah forest

By the 1970s, outbreaks of jarrah leaf miner (JLM) (*Perthida glyphopa*) had occurred in over 400 000 ha of jarrah forest (Mazanec 1974) and during the 1980s outbreaks of gum leaf skeletoniser (GLS) (*Uraba lugens*) had severely defoliated up to 300 000 ha (Strelein 1988; Abbott 1992a). Sixty permanent plots were installed throughout the jarrah forest to monitor JLM and 45 jarrah trees within a 50-km radius of Manjimup were selected to monitor GLS (Abbott 1992b). Abbott (1992b) compiled survey data and illustrated the spread and extent of outbreaks in a series of maps. By 1991 the GLS outbreak had abated (Abbott 1992b) and by the mid-1990s survey for JLM was restricted to the cut-out boundary (the northern line above which JLM populations remain at low levels) of the outbreak. GLS and JLM continue to be monitored, but on an ad hoc or opportunistic basis.

Bullseye borer in karri regrowth

In 1997 a survey using 15 sites across the range of 20–35-y-old karri regrowth found that defect associated with bullseye borer (*Phoracantha acanthocera*) was present in 24–78% of trees (Farr *et al.* 2000). Dry sites in close proximity to jarrah had the highest incidence and impact of attack. No further survey has been undertaken.

Figure 1. A disease front in jarrah forest infected with *Phytophthora cinnamomi*. Dead and dying *Xanthorrhoea preissii* and *Banksia grandis* and the almost total lack of understorey in the foreground indicate the disease boundary (Photo – DEC). **Figure 2.** Scar on the stem of a 30-y-old karri tree caused by *Armillaria luteobubalina* infection. **Figure 3.** Recently dead marri as a result of canker caused by *Quambalaria coyrecup*. **Figure 4.** Wandoo at Wundabiniring Brook showing symptoms of crown decline. **Figure 5.** Dead and declining tuart near Lake Clifton (Photo – THRG).

Marri decline

Marri (*Corymbia calophylla*) occurs throughout the south-west forest area, growing in conjunction with jarrah and karri. In the mid-1970s surveys near Dwellingup reported that 90% of marri trees had symptoms of 'cambial rupture and gumosis', and assessments of the crown condition of 70 trees carried out between 1975 and 1978 in the same region reported a 30% mean reduction in live crowns (McCormack in Kimber 1981). The canker-forming fungus *Sporotricium destructor* was identified as the possible cause (Kimber 1981). In the early 1990s reports identified an increase in canker formation and deaths of cankered trees (Fig. 3). Preliminary survey showed the canker to be severe and widespread throughout the south-west (Paap 2001). Subsequent surveys conducted annually at three locations during the period 2002–2005 showed that 27% of trees had perennial cankers and 48% had symptoms of cracking and kino exudation, early indicators of canker formation. The incidence of cankers was significantly higher in remnant, paddock and roadside trees (38%) than in forest trees (13%) (Paap 2006). The causal agent was identified as *Quambalaria coyrecup* (Paap *et al.* 2008), a native pathogen that also infects and kills red-flowering gum (*Corymbia ficifolia*) in urban plantings in WA.

Wandoo decline

Wandoo woodland occupies 218 680 ha in the south-west of WA. About 146 000 ha are managed as state forest and the remainder occurs on private land (Conservation Commission of Western Australia 2004). Wandoo woodland has undergone a series of decline events (Fig. 4) since the 1970s (Curry 1981; Mercer 1991, 2003). The pattern of decline is variable (Wills *et al.* 2000) and discontinuous across the landscape (Mercer 2003), and the most recent event appears to have started in the early 1990s (Mercer 2003). Symptoms involve a cycle of foliage chlorosis and death of small branches followed by a flush of epicormic growth that subsequently dies, often resulting in severe canopy decline (Hooper and Sivasithamparam 2005). In 2003, in response to community concern, the Minister for the Environment formed the Wandoo Recovery Group (WRG) to investigate the causes of decline and to develop appropriate strategies for recovery by developing collaborative partnerships and coordinating survey, monitoring and research.

The extent of past and present decline and crown condition are currently being mapped by:

- remote sensing using aerial photographs, Landsat images and airborne thematic mapping
- ground survey consisting of photo points, plots, road-side reconnaissance and visual assessment along transects (Wandoo Recovery Group 2006).

DEC and CSIRO are using a process known as Landsat Trend Analysis to assess wandoo canopy condition at the landscape scale. Changes in canopy condition over an 18-y period (1988–2005) were examined using Landsat Thematic Mapper. Trend analysis maps of the amount of change in declining, stable or recovering wandoo canopy at a number of locations were produced using Vegmachine™ software and checked by ground survey. Five broad areas were analysed with the result that across 60–70% of the area analysed the canopy appears to be stable (Bland *et al.* 2006).

A long-term photo point was established in 1999 to monitor changes in condition of a series of trees in declining open woodland at Wundabiniring Brook, about 65 km east of Perth (Wills *et al.* 2000; Wills 2006). The WRG has also developed a simple ground survey procedure for community groups, land managers, students and researchers to assess crown health of wandoo trees in their local area (Wandoo Recovery Group 2005). In 2006, 32 transects at 13 monitoring sites were surveyed (Whitford *et al.* 2007). Data are collated by the WRG and made available for research and monitoring, and to provide information on the geographic extent and severity of decline. These data will complement the broad-scale mapping undertaken by DEC and CSIRO.

Survey and research is ongoing. Results of some research and monitoring projects have been reported or published (Hooper and Sivasithamparam 2005; Bland *et al.* 2006; Wills 2006; Whitford *et al.* 2007) or are outlined in the *Wandoo Crown Decline Situation Statement* (Wandoo Recovery Group 2006). The WRG has a website (available at: www.naturebase.net) where further information on wandoo decline is available.

Tuart decline

Tuart (*E. gomphocephala*) woodlands occupy 30311 ha of the Swan Coastal Plain (Government of Western Australia 2003). A general decline in crown health followed by the death of many trees (Fig. 5) was noticeable in the mid-1990s, and in 1997 a major decline occurred near Preston Beach, about 30 km south of Mandurah. In 2002 aerial mapping and Landsat imagery were used to map the extent of the decline. Mapping showed that a marked increase in the extent of decline had occurred since 1999 and that over 90% of mapped areas had a canopy density of 50% or less (Government of Western Australia 2003).

In 2003, collaboration between Government agencies, universities and private industry lead to the Tuart Health Response Group (THRG) being initiated to coordinate research into the causes of tuart decline. While the THRG is focused on research it also continues to survey and map the spread and impact of decline. The extent of decline and change in canopy condition is surveyed and mapped by:

- remote sensing using aerial photographs and Landsat images
- ground survey consisting of permanent plots and opportunistic survey.

Landsat sensor spectral data were used to map trends in canopy condition over the previous 15 y. Aerial photographs of 46 sites throughout the range of tuart were also used to measure features such as fragmentation (Barber and Hardy 2006). Subsequent ground surveys were undertaken at all 46 sites to categorise canopy condition. At each site, plots containing at least 20 trees were assessed using estimates of canopy completeness, measures of canopy size reduction, and scores of canopy condition indices (Edwards *et al.* 2006). The plots will be used to monitor changes in canopy condition over time. In 2006 intensive surveys at Ludlow, Yalgorup and Yanchep revealed that *Mycosphaerella cryptica* was severely affecting young regrowth seedlings. Up to 25% of leaves on seedlings at Yalgorup were infected. Occasionally *M. cryptica* was associated with the death of seedlings in areas of dense growth (Barber *et al.* 2006).

The results of canopy surveys are analysed against environmental data including landform and climate variables, fire regimes and disturbance in order to determine research priorities, and conservation and management strategies, for tuart. The THRG has a website (www.tuarthealth.murdoch.edu.au) where a series of bulletins outlining preliminary results of research is available.

Mundulla yellows

Opportunistic surveys for the progressive dieback disease known as Mundulla yellows began in WA in the mid-1990s (Podger and Keane 2000). The disease appears to have a scattered distribution throughout WA and affects at least 23 species of eucalypts (Podger 2002) as well as species of *Allocasuarina*, *Banksia* and *Acacia* (Hanold *et al.* 2002). In 2000–2001, roadside surveys were conducted in the south-west along about 1000 km of roads extending from the Perth metropolitan area south to Busselton. Trees from 86 sites were recorded as having symptoms (Hanold *et al.* 2006). As yet trees with symptoms have not been observed or recorded in undisturbed forest or woodland. Monitoring symptom development in selected trees is ongoing at a number of sites.

Forest health surveillance and monitoring in blue gum plantations

Almost all blue gum plantations in WA are now privately owned. In 1998, the first formal blue gum health surveys were conducted in 2.5- and 3.5-y-old plantations from 32 tree farms between Bunbury and Albany. Juvenile and adult foliage was assessed for 13 symptoms related to leaf condition resulting from disorders caused by fungi and chewing insects (Boland *et al.* 1998). In this first survey, drive-by, transect and plot surveys were compared in order to establish a standard method for a future industry-wide forest health surveillance system. The survey showed that the symptoms with the highest incidence and severity were leaf chewing, leaf spot and chrysomelid damage. Drive-by surveys were useful for an overall impression of plantation health but were not as accurate as plot or transect surveys. The survey also showed that increasing the number of trees sampled significantly improved the precision of severity scores. The success of the survey lead to the formation of the Industry Pest Management Group (IPMG), jointly funded by blue gum industry partners and the Forestry CRC, and a full-time entomologist to carry out industry-wide forest health surveillance. The IPMG concentrates on insect pest surveillance and contributes to funding for fungal pathogen surveys and research, mainly through Murdoch University.

Fungal pathogens

Since 1998, Murdoch University, in co-operation with private plantation companies, has undertaken most survey and research projects in blue gum plantations. The emphasis has been on leaf and canker pathogens such as *Mycosphaerella* spp., *Botrysphaeria* spp. and *Holocryphia eucalypti* (= *Endothiella eucalypti*, but note that only the anamorph has been recorded in WA) (Maxwell *et al.* 1998; Tovar 1998; Jackson 2003; Maxwell 2004) and decay fungi infecting coppiced stumps (Tovar *et al.* 2007).

A number of surveys have been conducted to determine the incidence of cankers in blue gum plantations in the south-west. The incidence of trees with cankers ranged from 12% (Jackson 2003) to 16% (Maxwell *et al.* 1998). The proportion of cankers caused by *H. eucalypti* ranged from 27% (Tovar 1998) to 53% (Jackson 2003). Other identified species associated with cankers were *Botrysphaeria australis* (10%) and *Cytospora eucalypticola* (51%) (Tovar 1998). Although *H. eucalypti* was widespread, its overall incidence was only 6.6%, with the highest incidence, 15.7%, around Bunbury (Jackson 2003). The teleomorph of *H. eucalypti* has not been recorded in WA (Nakabonge *et al.* 2008).

Fifteen species of *Mycosphaerella* have so far been recorded in surveys in blue gum plantations. These species are: *M. ambiphylla*, *M. aurantia*, *M. cryptica*, *M. ellipsoidea*, *M. fori*, *M. gregaria*, *M. lateralis*, *M. marksii*, *M. mexicana*, *M. molleriana*, *M. nubilosa*, *M. parva*, *M. suberosa*, *M. suttoniae* and *M. tasmaniensis* (Carnegie *et al.* 1997; Maxwell *et al.* 2003; Maxwell 2004; Jackson *et al.* 2005, 2008). The first survey in 1994 recorded three species on blue gums: *M. cryptica*, *M. marksii* and *M. suberosa* (Carnegie *et al.* 1997). In 1998, Maxwell (2004) recorded 10 species during ground transect surveys conducted in 1–2-y-old plantations at three locations between Albany and Manjimup. Surveys were designed to determine the incidence and severity of mycosphaerella leaf blight (MLB), insect pest damage and nutrient disorders. MLB (Fig. 6) was shown to be the most severe and frequently occurring health problem. Severity of MLB across the sites was 1–3% foliar necrosis but varied considerably between sites (0–50% foliar necrosis) and was related to the species of mycosphaerella present, inoculum levels and local climatic conditions favourable for disease (Maxwell 2004). Of the 10 species recorded in the survey, the most common and widespread species was *M. nubilosa*, which was not recorded in the 1994 survey by Carnegie *et al.* (1997). It is possibly a recent introduction from eastern Australia, or perhaps it previously had a very low incidence but responded rapidly to the expansion of blue gum plantings since 1997 (Maxwell *et al.* 2001). In 2003, in a 2-y-old multiple provenance trial near Albany, Jackson *et al.* (2008) recorded 11 species of mycosphaerella from a single plantation. The species most frequently isolated from juvenile foliage were *M. marksii* (77%) and *M. nubilosa* (33%) and from adult foliage was *M. nubilosa* (88%). A key to 11 species of mycosphaerella occurring on blue gums in WA (Maxwell *et al.* 2003) enables the identification of most species recorded in surveys.

Following reports of significant loss of coppice due to wind-throw, surveys of wood decay fungi in live coppice stumps were undertaken from 2005–2007 in 18 plantations throughout the south-west plantation-growing region. Coppice was 18–24 months old when surveyed. Six species of fungi were common in most plantations: *Trametes versicolor*, *Stereum illudens*, *S. hirsutum*, *Pycnoporus coccineus* and two unidentified species (Tovar *et al.* 2007). The proportion of stumps colonised by each species varied regionally for some species. It appears that some species of wood decay fungi rapidly colonised fresh stumps at any time of the year, or they were already present in trees prior to harvest. Survey showed that loss from decay-associated wind-throw was less than 1%, but evidence that *S. hirsutum* can colonise the base of coppice from infected stumps was also found (Fig. 7); this could result in losses from rot as coppice reaches harvest age (Tovar *et al.* 2007).

Insect pests

Since 1999, an entomologist with the blue gum IPMG has conducted regular and extensive insect pest surveys and recommended control strategies for a number of priority pests (Table 3). Control measures, including spraying, are undertaken when necessary. Adult nocturnal *Heteronyx* beetles (Fig. 8) are considered one of the most significant pests of blue gums in the south-west, defoliating tops of trees (Fig. 10) in the region from Rocky Gully to Esperance. Prior to 2002, the loss of seedlings due to African black beetle (*Heteronychus arator*) was significant, but the introduction of 'socks' (Fig. 9) on seedlings prior to planting has reduced the impact to almost nil. Other pests and prominent leaf pathogens are also recorded and surveyed for when necessary, including 'spring' beetle (*Liparetrus jenkinsi*), leaf blister sawfly (*Phylacteophaga froggatti*), Rutherglen bug (*Nysius vinitor*), autumn gum moth (*Mnesampela privata*), chrysomelid beetles (mainly *Paropsisterna variicollis*) and leaf disease (*Mycosphaerella* spp.).

Forest health surveillance and monitoring in pine plantations

European house borer

In January 2004, an incursion of European house borer (*Hylotrupes bajulus*) (EHB) occurred in Perth. While not a pest of living trees, *H. bajulus* can utilise dead *Pinus* spp. trees, as well as untreated pine timber, to complete its life cycle. The generic Incursion Management Plan was initiated with the Department of Agriculture as the lead agency. An EHB response group, made up of personnel from the Department of Agriculture, FPC and DEC, undertakes annual surveillance of dead pine trees on all gazetted roads between Geraldton and Esperance, and surveys all metropolitan and regional radiata and maritime pine plantations inland to the 400 mm isohyet. Infested trees are removed and destroyed. As part of surveillance, the EHB response group

Table 3. Insect pest surveys and control measures conducted by the IPMG in blue gum plantations in the south-west (M. Matsuki, IPMG, 2008, *pers. comm.*)

Pest species	Region surveyed	Age of trees affected	Time of survey	Control actions
Day-time scarab beetle, *Liparetrus jenkinsi*	Esperance to Collie	Seedlings	Visit high-risk plantations repeatedly on warm days from late August to early November to detect swarming.	Spray when swarming is detected
Nocturnal scarab beetle, *Heteronyx proxima*	Esperance	All ages	Visit high-risk plantations repeatedly from December to March to detect damage.	Spraying is not effective because the abundance of this species is highly variable temporally and spatially. Systemic insecticides have been trialled.
Nocturnal scarab beetle, *Heteronyx elongatus*	Esperance to Collie	Seedlings	Visit high-risk plantations repeatedly from December to March to detect damage.	Spray when damage is detected
Eucalyptus weevil, *Gonipterus scutellatus*	60 km east of Albany to Collie	2–4-y-old trees	A small number of 2-y-old plantations are visited weekly from mid-August to late October to detect eggs. Once detected, population assessments, based on egg counts, are conducted once in each 2–4-y-old plantation.	Timing of the population assessment is determined by the phenology study. Any management response is based on the number of egg cases in each plantation. Spraying should occur two to three weeks after the population assessment.
Wingless grasshopper, *Phaulacridium vittatum*	Esperance to Collie	Seedlings	Visit high-risk plantations repeatedly from November to March to monitor build-up of insect numbers.	Spray or deploy baits when grasshopper numbers build up and there is no alternative food for them.

Figure 6. Damage to blue gum foliage caused by mycosphaerella leaf blight (Photo – A. Maxwell). **Figure 7.** Rot, caused by *Stereum hirsutum*, spreading from the stem of the original stump on the left into the stem of the living 2-y-old blue gum coppice on the right. **Figure 8.** Night scarabs (*Heteronyx* sp.) and typical damage to blue gum leaves caused by chewing (Photo – A. Loch). **Figure 9.** Blue gum seedling showing the mesh 'sock', fitted over seedlings prior to planting, to prevent damage or loss due to African black beetle. **Figure 10.** Damage to 2-y-old trees in blue gum plantation caused by *Heteronyx* sp. (Photo – M. Matsuki).

installed almost 900 trap poles and door-knocked more than 43 000 homes. In 2006, the infestation was confined to 102 sites within the outer metropolitan area, and regulations have been introduced that prohibit the movement of untreated pine timber out of affected areas. However, surveys of regional plantations continue. The EHB response group has a web site (http://www.ehb.gov.wa.au) with up-to-date information regarding European house borer surveillance and research.

Sirex wasp

The FPC conducts annual detection and monitoring surveys for sirex wasp (*Sirex noctilio*) throughout the range of mature pine plantations. Fifty-two trap tree plots have been established in mature plantations throughout the estate, with a focus on areas considered to be at higher risk, and are monitored from November to March. To date no wasps have been recorded (I. Dumbrell, FPC, 2008, *pers. comm.*).

The future: a forest health and vitality program for native forest

Under conditions within the Forest Management Plan 2004–13 (Conservation Commission of Western Australia 2004), DEC is required to implement a forest health surveillance system for native forest within the next 5 y. In 2006 a forest health and vitality (FH&V) project was initiated. The objectives of the FH&V project are to firstly develop survey methodology and then to maintain an up-to-date register of forest condition, and the presence and severity status of pests, diseases and weeds of concern — initially in state forest and timber reserves but with a design that could be extended to include the whole DEC estate. Fulfilment of these objectives will facilitate (i) reporting of forest health and vitality, and (ii) implementation of pest, disease and weed control programs.

Traditional utilitarian perceptions of forest health surveillance involve monitoring pests and pathogens that potentially threaten the productive capacity of a forest in terms of its timber and or other product output. Contemporary concepts of forest health involve both utilitarian and ecosystem perspectives, and surveillance requires monitoring for production management objectives as well as the long-term functioning of ecosystems, i.e. organisms and trophic networks functioning within the forest (Kolb *et al.* 1994). In 1992 the Montreal Process introduced the concept of sustainable forest management, which involves monitoring forest health and vitality against threatening processes in respect to entire ecological communities (Montreal Process Implementation Group 1998). DEC's commitment to sustainable forest management and maintaining biodiversity means the proposed FH&V project will encompass a more holistic ecosystem health approach in addition to the traditional pest and pathogen surveys. The accepted system also needs to be comprehensive, practicable, achievable and affordable. Ideally the framework should be so robust that it could be readily adopted for plantations and other land categories beyond the forest management plan land area. An options paper on methodologies and management of the system has been prepared by the Science Division for consideration by other divisions within DEC[2].

Conclusions

The major forest health problems in WA presently occur in native forest. Those of most concern are dieback caused by *P. cinnamomi* in jarrah forest, tuart and wandoo decline, marri canker and armillaria root disease in karri regrowth forest. The most widespread problem in blue gum plantations is mycosphaerella leaf disease which may be locally severe but not yet at levels to be problematic throughout the region. No formal FHS program operates in WA. However, systematic surveys to map the distribution of *P. cinnamomi* have been ongoing since 1978. The surveys are linked to the harvest plan for jarrah forest in timber reserves and to conservation objectives in national parks and conservation reserves. Other surveys for pests and pathogens affecting forest health are undertaken in an ad hoc fashion, and are usually included in forest health research projects. As a result many surveys are 'one off' or of short (1–3 y) duration. Most surveys record the incidence of pests and pathogens but not their impact. At present, there is no systematic process for reporting results of surveys, but major findings are compiled and reported in the *Annual Pest and Disease Status Report for Australia and New Zealand* by Research Working Group 7 (Forest Health). However, these reports are currently not readily available.

The lack of a formal FHS system means that many forest health problems are not reported or acted upon until they are well advanced. Examples include tuart and wandoo decline. Most research associated with forest health problems is not pro-active but results from opportunistic observation of changes in tree health status, usually reported by forest or plantation workers and brought to the attention of land managers or forest researchers. A formal FHS program would detect potential problems, determine impacts, map the extent and inform land managers in a systematic and informative process that, in many cases, would allow research and control action to be included in future planning rather than being reactionary.

A formal FHS system is needed to coordinate and standardise forest health survey in WA. In native forest, DEC is to initiate a FHS program within the next 5 y (Conservation Commission of Western Australia 2004). To facilitate required forest health reporting, the program will be initiated in state forest timber reserves but will later encompass all lands managed by DEC. In plantations, IPMG undertakes systematic pest survey in blue gums, but in pine plantations formal survey is restricted to European house borer (EHB response group) and sirex wasp (FPC); all other survey is ad hoc. Ideally, a formal system suited to both native forest and plantations would enhance the prospects of a coordinated approach for reporting forest health status in WA to satisfy local, national and international requirements.

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[2] Robinson, R.M. and Farr, J.D. (2006) Forest health and vitality project: monitoring forest health – options paper. Unpublished internal report. Department of Environment and Conservation, Kensington, Western Australia.

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