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Ground Surveys to Assess Forest Health:

Sampling Strategies in Regrowth Native Forests

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ABSTRACT

At present formal Forest Health Surveillance of regrowth native forests is not practised in Australia. As changes in forest policy come into effect, regrowth forests will become increasingly important in meeting the demands of the forest industry. This paper reviews past and present survey techniques used in detecting pests and pathogens in regrowth forests and suggests strategies for ground survey which could be integrated into a formal system of Forest Health Surveillance. A current survey technique used in Western Australia for detecting and mapping Armillaria root disease in karri regrowth forests is also presented in detail.

INTRODUCTION

At present Forest Health Surveillance (FHS) of plantations is formally undertaken in NZ, TAS, NSW and QLD. In WA one plantation management company has initiated its own Forest Health Survey and all major growers have recently formed an Industry Pest Management Group to monitor and manage pests in their plantations (Fremlin 1998). In the ACT, FHS of plantations will be contracted to the State Forests of NSW. In contrast, formal FHS in regrowth native forests is only practised in QLD; however, reduction in funding precludes regular survey (Hood *et al.* 1999). In native regrowth forests in WA., formal surveys are conducted on a continual basis to detect the presence of *Phytophthora cinnamoni*, annually to detect *Armillaria luteobubalina* and every 2-5 years (depending on severity of outbreak) to monitor the jarrah leafminer (*Perthida glyphopa*) front.

In general, knowledge regarding the state of health of native regrowth forests in Australia relies on opportunistic detection by experienced field based staff and these data being recorded formally. Often the data are recorded but then the information rarely leaves the confines of the District Office concerned unless it is entered onto a Department-wide database and collated with information from all districts and regions. This is rarely the case.

With changing policies, the area of mature forest made available for production will likely be reduced. Regrowth native forests will become increasingly important in meeting the demands of the forest industry. The future will also see a rapid expansion of native species plantations often alongside regrowth native forests. There are many species of fungi and insects, some of them indigenous, already contributing to damage in both plantations and native regrowth forests. These include *Mycosphaerella* spp., canker fungi such as *Endothia gyrosa*, species of Polyporaceae, *Phytophthora cinnamomi, Armillaria* spp., bullseye borer (*Phoracantha acanthocera*), jarrah leafminer, psyllids (*Cardiaspina* spp.), species of chrysomelids and gum leaf skeletoniser (*Uraba lugens*). The full impact on production of many of these pathogens and pests has not been investigated. Alongside pathogens and pests there is also damage and deficiency caused by both biotic and abiotic agents, such as mechanical damage from management operations, nutrient deficiency and drought. Thus there is a need for formal FHS of regrowth native forests not only to enhance the probability of early detection of new forest pests and pathogens but to gain knowledge of existing pests and pathogens which may threaten the health of the regrowth estate in the future.

SURVEY METHODS

To aid in covering an extensive area of regrowth forest, aerial survey and aerial photography can be used in conjunction with ground-based survey. Methods for ground-based survey may include:

- Opportunistic detection by field-based staff
- Roadside or drive by surveys
- Ground surveys including:
    - transects
    - plots
    - confirmation of symptoms detected on aerial photos
- Insect trapping including:
    - pheromone traps
    - light traps
    - attractive sticky traps
- Insect egg, larvae and adult counts
- Laboratory diagnosis
    - processing material
    - identification of specimens
- Informal interaction with forest-based workers.

Table 1 gives a summary of methods available for ground-based survey in regrowth native forests.

Table 1. Summary of ground-based survey methods available for Forest Health Surveillance in regrowth native forests.

METHOD	ADVANTAGES	DISADVANTAGES
Opportunistic detection by forest-based staff	• Low relative cost • Staff are consistently in the field	• Requires ongoing training • Subject to personal interest • Staff often have time constraints when on site • Low percent of regrowth estate visited on an annual basis • variable consistency of data between Districts
Roadside and drive-by surveys	• Low-moderate relative cost • Large area covered • Annual survey possible	• Survey is low intensity • Roads need to be maintained • Only obvious/high impact symptoms detected
Ground survey	• High intensity survey • Measures incidence and severity • Quantitative data which are statistically valid • Spatial and temporal continuity in data from plots	• High relative cost • Understorey and/or steep and rugged terrain may limit access to some stands • Limited access to canopy in older stands
Insect trapping	• Allows detection of mobile and cryptic insects • Measure temporal trends • Traps can be set and left	• High diagnostic costs • Requires regular monitoring and maintenance • May modify insect behaviour, eg. attracting traps • Measures relative data and needs to be combined with methods such as counts (below) to determine absolute measures
Larvae/egg counts	• Provides quantitative data • measures intensity	• High diagnostic costs • Time consuming • Limited access to canopy in older stands
Laboratory diagnosis	• Provides identification of damaging agents	• High relative cost • Requires access to specialist staff
Informal interaction with forest-based workers	• Low relative cost • Forest-based workers often have a vast local knowledge and a keen awareness of changes in forest health over long periods of time	• Relies on personal interest • Colloquial information may be inconsistent

1. Opportunistic detection by ground-based staff.

This relies on field-based staff detecting and reporting occurrences of outbreaks during the normal course of their duties. Voucher specimens need to be collected, the symptoms and severity recorded, and map references entered into a Forest Health Database. This enables a wider range of sites to be inspected than is normally possible by a single pathologist. However, visits to regrowth stands are usually related to management activities, and once established, regrowth stands may not be visited again until the scheduled first thinning. Once on site, field staff priorities often do not include time for disease detection. This system is only reliable if field staff are trained in pest and disease recognition and there is a system in place to record and disseminate the information. Staff turnover necessitates ongoing training. The effectiveness of the system relies on experienced staff who have a personal interest in forest health and the availability of specialised staff to conduct training and collate data.

2. Roadside or drive-by surveys.
Intensity of drive-by surveys depends on the amount of roading within the forest. However, many roads through regrowth stands are not maintained, and often their accessibility cannot be determined from maps. If available, aerial photos are helpful in planning drive-by routes. Drive-bys should be conducted at speeds of 10-15 kph, with random stops to conduct transect or plot inspections. Any observed symptoms should be noted and the location marked accurately on a map accompanied by a GPS reading. For unfamiliar symptoms, voucher specimens should be collected for laboratory diagnosis.

3. Ground Surveys.
Ground surveys can be conducted in conjunction with drive-by surveys or be undertaken specifically for a particular pathogen or pest and/or in relation to management activities. For root diseases, ground evaluations are efficient if areas are small or if precise disease location and damage measurements are required (Morrison *et al.* 1991). They should also be undertaken to verify symptoms found on aerial photo and during drive by surveys. Surveys can consist of regularly spaced or random transects through, or plots within, a regrowth stand. Transects and plots allow incidence and severity to be examined. The area covered by ground will vary according to terrain and understorey, but ideally should aim to cover at least 1 ha for each 100 ha of regrowth.

4. Insect Trapping.
Pheromone traps have not been used in native regrowth forests for pest detection. They have been used for early detection of the pine pests, *Ips grandicollis* and Asian gypsy moth (*Lymantria dispar*) in Tasmania (Wardlaw 1996) and trap trees have been used in Victoria to detect and control *Sirex* wood wasp (Neumann and Marx 1989). However, Asian gypsy moth is also known to feed on species of *Eucalyptus, Acacia, Leptospermum* and *Nothofagus* (Wylie *et al.* 1996). Traps are normally set near ports and results can be used as an indicator of their presence.

In WA, light traps have been used to determine densities of initial outbreaks of gumleaf skeletoniser (Strelein 1988), and to determine flight periods of bullseye borer (Farr unpubl.), and attractive (yellow) sticky traps have been used in flat top yate swamps to determine population peaks of the lerp *Cardiaspina jerramungae* and to compare a range of widely dispersed sites (Farr unpubl.). Curry and Humphries (1988) used light, Malaise and pitfall traps to assess the impact of forestry practices on insect communities in WA karri forests. Insect trapping programmes require a considerable commitment in manpower to place and service traps and to process and identify collected material (Wylie and Peters 1987).

5. Insect Larval/Egg Counts.
To carry out larval/egg counts requires access to leaves. Access in taller, older trees is difficult and safety and cost factors require careful assessment. Other problems with estimating populations arise if the biology of the pest is not known or poorly understood. For example, autumn gum moth (*Mnesampela privata*) has clumped larvae and eggs, Chrysomelids lay more than one egg batch, gumleaf skeletoniser lays one clumped egg batch and when larvae hatch they are clumped then disperse later in season, and some species of Lepidoptera (eg. Cossids) lay multiple single eggs. Methodological issues such as whether to count the eggs or the larvae, and the time of survey will depend on the level of knowledge of the biology of the pest concerned. Errors in over or under estimation could result.

6. Laboratory diagnosis.
Although many of the pathogens and pests encountered are familiar and easily identified, some are not. Voucher specimens need to be collected and identified by pathologists and entomologists. Good quality specimens, well maintained collections and locality data are essential for verification of field identification or for identification of new encounters. The information then needs to be entered into a Forest Health Database. Sorting of specimens and identification relies on access to the services of experienced specialists.

8. Informal interaction with forest-based workers.
Liaison by the Forest Health Officer and field-based staff with forest-based workers outside the Forest Authority is often a valuable exercise. As is the case with field based-staff, forest-based workers often have a keen awareness of changes in forest health.

SAMPLING STRATEGIES FOR GROUND SURVEY

A major consideration is the intensity of survey to be undertaken across the regrowth estate. Regrowth is managed on a commercial basis, so the survey must be cost-effective. As surveillance develops, statistical analyses on data collected will help refine optimal sampling numbers and the suitability of plots or transects as effective sampling units for specific pathogens or pests. Techniques such as resampling (Speijers and Boland 1998) will be invaluable in developing cost-effective sampling. It may be very difficult to cover the whole regrowth estate in a uniform manner, therefore it can be stratified on a priority basis, covering high risk areas first. High risk areas are more likely to yield new introductions. Examples of high risk areas include, regrowth alongside a monoculture plantation, newly established regrowth on a poor quality site or stands subjected to a stress event (such as prolonged drought). Initial FHS should be of a low intensity concentrating on detection and extent, following up where necessary with high intensity survey to determine impact.

Plantation surveys can follow rows of trees and be based on the number of trees. In regrowth, however, linear sampling is not possible. Transects or plots have to be assessed by area and the numbers of trees assessed within a stand may be different for each transect or plot and will vary greatly with stand age and management. For example planted karri (*Eucalyptus diversicolor*) is stocked at 1,666-3000 stems/ha (CALM 1997) and seeded regrowth may be 10,000-15,000 stems/ha at age 1 (M. Rayner[1], pers. comm.), numbers will decline with age through natural suppression and then be reduced to 250-400 stems/ha after the first thinning at age 25-30 years (CALM 1992). Thus the appropriate sample size for unbiassed assessment will also vary with the age and management history of the stand.

Tree size will also vary greatly within a regrowth stand, and tree death due to suppression needs to be distinguished from death due to disease. Often suppression deaths indicate the presence of Armillaria root disease (ARD). If present on site, *Armillaria* spp. will readily infect suppressed trees and the disease will express itself with the presence of mycelial fans under the bark at the root collar or by clusters of fruitbodies at the base of the tree in the autumn. Tall trees also make it difficult to assess damage from leaf pathogens or pests unless it is very obvious. In such cases binoculars can be used to examine canopies.

Sampling may be further complicated in mixed species stands where host specific pathogens and pests are present. This may mean a wider variety of pathogens and pests, with a patchy distribution. In such circumstances transects should be more appropriate than plots, which may be centred within the patches and give a false impression of uniform distribution through the stand. If pathogens or pests are detected, the susceptibility of each species and the proportion of susceptible trees in the stand should be determined.

In regrowth, transects are often undertaken in difficult conditions. This is especially so in wet sclerophyll regrowth where the understorey is often very dense and tall. On the other hand symptoms in understorey species may act as indicators for non-obvious root diseases such as dieback due to *Phytophthora* spp. (Podger 1972, Shearer and Dillon 1995) or ARD caused by *Armillaria* spp.

Intensive management will also affect sampling strategies in regrowth native forests. Many damaging agents are initially an integral part of the forest ecosystem and imposed disturbance, in the form of forest management, may change conditions to favour the pathogen or pest. In such cases surveys should be conducted before, in conjunction with and/or after management operations. Mechanical damage to retained trees may result in the introduction of decay organisms through the wounds (White and Kile 1991). Thinning slash may provide a substrate for the introduction of new pathogens or pests. Thinning may also result in an initial increase of pathogen or pest intensity, for example *Armillaria* spp. colonising fresh stumps and Chrysomelid populations feeding on a smaller amount of foliage. Hazard reduction burning will reduce the amount of scrub in the understorey, making it easier to survey transects. This may remove alternate hosts for some diseases but it will also reduce the number of "indicator species" present and remove substrates for pest parasitoids. Such areas

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will need to have follow up surveys once the understorey has returned. Health surveillance may also be included in scheduled silvicultural assessment of regrowth stands or Forest Health Officers could use permanent silviculture inventory plots for health surveillance. In the southeastern United States, an inventory of damaging agents across five States has successfully been incorporated in Renewable Resource Evaluation (RRE) State surveys. The co-operation between Forest Pest Management and RRE has been cost effective and the data provide such attributes as: (i) a large number of plots systematically located across five States, (ii) statistically valid samples, (iii) valid regional comparisons and (iv) accurate measures of change because plots are revisited (Jacobi *et al.* 1981).

Most disease and damage can be identified by obvious symptoms. Stem cankers, leaf pathogens and pests, crown dieback, borers and fire damage can be identified by cankering of the bark, spots and chewing on the leaves, dead and dying limbs in the crown, frass emerging from pinholes, or large emergence holes in stem bark and scars healing on the lower stem. However, some diseases do not show obvious symptoms and Forest Health Officers must be trained to recognise other signs which indicate the presence of a particular pathogen or pest. Examples of such diseases include root diseases, degrade caused by discolouration and decay, cerambycid and some termite damage and bark beetle damage. Soil samples may need to be taken to detect and identify some soil-borne pathogens. The presence of other root diseases may be expressed by symptoms showing in the above ground portion of the tree or in causing the death of understorey species. The use of "indicator species" for the assessment of *P. cinnamomi* and *Armillaria* spp. has been discussed above. However, the impact of a pathogen may be overestimated if it is acting in a secondary capacity only. Root diseases may also be expressed as crown decline and ARD can also be identified by the presence of inverted V-shaped scars extending from the base of trees, mycelial fans under the bark at the root collar and distinctive fruitbodies at the base of trees in the autumn. Fire scars, mechanical scars and broken limbs in the crown indicate that decay may be present, while fruitbodies emerging from behind the bark on the stem or on large crown limbs are indicative of advanced decay.

Counting the number of insect pests (or their eggs or larvae, see above) along a transect or in a plot can be useful in determining an absolute estimate of population. This can be expressed several ways; as an absolute population (number of animals per unit ground area), population intensity (number of animals per unit of habitat) or basic population (number of animals per unit area of habitat) (Southwood 1989). It is often more efficient to stratify the sampling in order to reduce the variance (ie. sample a particular part of a tree, such as new or old expanded leaves, juvenile or adult foliage). These levels are thus measured against a benchmark (leaf area, leaf weight, per leaf etc) and are usually only applicable to a particular insect species (Fig 1). In order to sample adequately for a particular pest the biology, habit, life cycle timing and host phenology need to be considered. The time and frequency of sampling and the means of sampling will vary for each species.

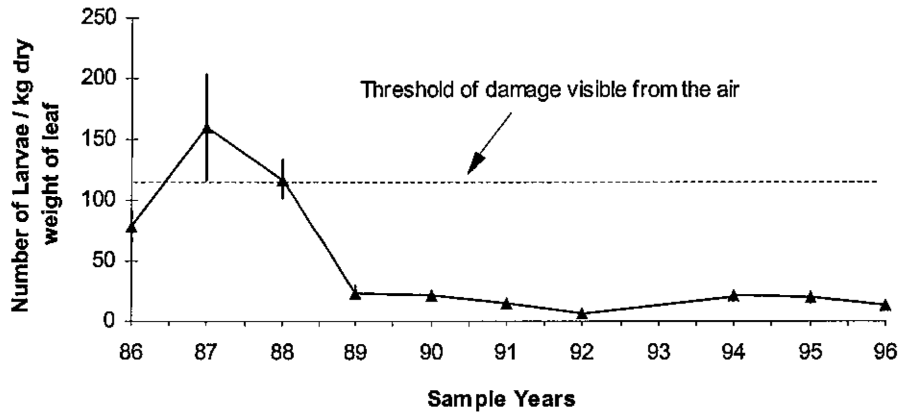

Figure 1. The population of gumleaf skeletoniser (*Uraba lugens*) determined from larval counts per kg of dry leaf weight. Data collected in permanent plots in jarrah regrowth forests in Western Australia from 1986-96 (Farr, unpubl.).

Relative estimates of insect populations can be obtained by strategies such as the use of pheromone and light or attractive sticky traps (see above). With these methods the population is measured in unknown units allowing for comparisons in space and time only (Southwood 1989). The results depend on a number of factors besides population, such as changes in actual numbers, changes in insects in a particular "phase", changes in activity following changes in environment, response of sex and species to trap stimulus. Used in peak activity periods, traps can be useful in estimating density and providing general information or used in conjunction with absolute methods to develop correction factors.

Population indices can also be determined by measuring the effect of the pest on the tree or the magnitude of their products. The animals themselves are not counted but their products (frass, leaf cut outs, moulting casts etc) and their effects (plant damage, kino dribble, exit vents etc) are counted or measured (Southwood 1989). Kino dribble emerging through the bark on stems may indicate damage by cerambycids, such as bullseye borer, which may be common on stressed sites (Farr in prep.). However, care must be used when interpreting cryptic symptoms. Kino dribble, for example, is a sound indicator of bullseye borer in the smooth barked karri (Fig.2) but the rough barked marri (*Corymbia calophylla*) produces kino dribbles for other reasons.

The estimation of absolute populations from relative estimates and population indices is difficult. Mazanec (1978) estimated jarrah leaf miner population density from counts of laval cells caught in cone traps beneath trees and mature lavae on leaves collected from the upper and lower canopy. When estimates are determined the decision still has to be made as to whether the insect levels are tolerable, critical or intolerable.

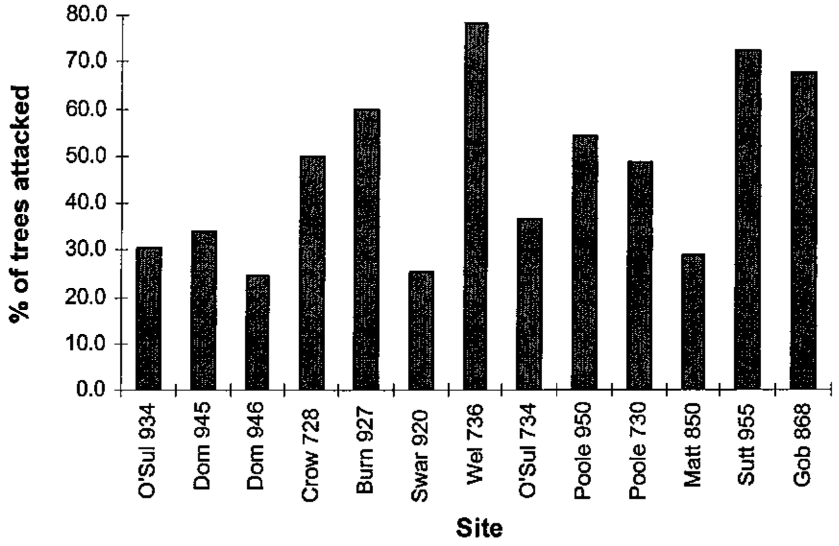

Figure 2. Bullseye borer (*Phoracantha acanthocera*) infestation at 13 sites in 20-30 year old karri regrowth in Western Australia in 1997. The number of trees attacked was estimated by counting kino dribble, emergence holes, vents and frass on tree stems (Farr, unpubl.).

OUTCOME OF SURVEILLANCE

The information collected needs to be entered onto a central database and collated. Routine reports on the health status of native regrowth forests, including distributions and risk analyses of "high priority" pathogens and pests need to be circulated to forest managers. Commercial forestry in Australia is dominated by native species. An increase in the eucalypt plantation estate is likely to increase the status of some local pathogens and pests (Wylie *et al.* 1996). Therefore most problems should be caused by native rather than exotic pathogens and pests. The initial outcome of FHS in native regrowth forests should be an inventory of the occurrence of pathogens and pests, their natural levels, and whether or not they are causing damage or disease which needs to be controlled. Questions of whether or not a particular pathogen or pest is amenable to control, has the potential to cause problems in the future and requires further monitoring then need to be addressed.

THE EVOLUTION OF A STRATEGY FOR GROUND SURVEY OF ARMILLARIA ROOT DISEASE IN KARRI REGROWTH FORESTS IN THE SOUTH-WEST OF WESTERN AUSTRALIA

One of a number of approaches to detect and manage Armillaria root disease (ARD) in the karri regrowth forests of southwestern Australia has been the establishment and ongoing development of a ground survey. The survey is used to ascertain whether and/or where ARD warrants further detailed survey. Prior to 1994, the occurrence of ARD in the karri forests of the southwest of Western Australia was noted from opportunistic observation by field-based staff. All observations were recorded on an Integrated Management Control Information System.

Armillaria root disease is relevant to forest management in two ways: the effect the pathogen may have on regrowth karri stands; and the effect that intensive forest management may have on the disease. Since 1995, formal surveys for the presence of *Armillaria luteobubalina* have been undertaken to assist the planning of operations in regrowth karri stands. Strip line surveys are carried out during the *Armillaria* fruiting season between May and July. Evidence of the presence of Armillaria is based on the sightings of fruiting bodies and/or scarring at the base of infected trees. Each year, prior to surveys commencing, all survey personnel attend a one day workshop where instruction on the recognition of *A. luteobubalina* and host symptoms of ARD is presented. Also presented are strict guidelines on how to conduct the survey, followed with practice by crews in the field. The survey technique is reviewed annually and modifications implemented in order to accommodate new knowledge and to maximise cost efficiency.

Surveys are conducted in compartments scheduled for first thinning. Maps of each compartment are prepared with transects to be surveyed marked at 20m intervals. Initially crews of two people strip surveyed entire coupes by covering 10m either side of each transect. Trees and shrubs showing symptoms of infection and sightings of *A. luteobubalina* fruitbodies were marked with flagging tape and recorded on field sheets based on distance along a transect line.

Following feedback from crews and an artificial simulation on the 1996 results, the method was reviewed and improved for 1997. In thick understorey a third member was added to act as lineman and recorder. This improved both the efficiency of the crew and the chance of sighting symptoms. Survey intensity within each coupe became dependent on the extent and severity of ARD detected at the completion of each transect. The extent and severity was quantified by (i) the number of trees with symptoms, and/or sightings of fruitbodies per 200 m distance of transect, (ii) the dominance class of the tree(s) with symptoms, and (iii) whether the pathogen appears to be isolated in one tree or is infecting a group of adjacent trees (see Appendix 1). Infected hosts were classified as either Category 1 or Category 2. Category 1 is an infected dominant, co-dominant or sub-dominant tree or an infected stump left following logging. Category 2 is an infected suppressed tree or understorey shrub or *A. luteobubalina* fruiting on the ground. The categories reflect the inoculum potential (see Redfern and Filip 1991) of the infected host and thus the ability of the pathogen to spread from the host root system to a healthy neighbouring tree. The survey thus places more emphasis on substrates with high inoculum potential.

Crews choose where to begin survey, but must survey a pair of transects for every 100m of coupe width. Higher intensity will be governed by the guidelines of the Survey Prescription. When the presence of ARD has been predicted from Aerial Photo Interpretation, red transect lines on the survey maps will indicate transects which must be included in the survey. Survey results are recorded on Survey Data Field Sheets (see Appendix 2). Crews also fill out Costing Sheets at the end of each day.

Success of the survey relies on crews making decisions in the field. The workshop provides all personnel with appropriate training and standards control. Inexperienced personnel are teamed with an experienced partner. Crews select transects based on practicality and accessibility, after considering terrain, vegetation, road access and the ability to locate transect start and end points on the map and in the field. They then assess the results at the end of each transect and make decisions regarding survey intensity. Crew morale is very important and is kept high by the addition of an extra member for survey through thick understorey, and by emphasising that their results have a direct impact on stand management decisions.

Survey results are entered into a Microstation95 (Bentley, USA) design file. A detailed map of each survey area is prepared as a basis for the harvest concept plan. On each map, a nominal 25 m buffer zone is placed round each recorded infection site to indicate a possible exclusion zone for thinning (Appendix 3). The width of the buffer is based on the correlation of crown diameter with root zone diameter for *E. regnans* (Ashton 1975) and the "zone of influence", of twice the radius of the crown, a veteran karri tree exerts on the growth of surrounding regeneration (Rotheram 1983). The 25 m buffer zone is thus an estimate of the maximum radius of the roots extending from the base of an infected tree based on the maximum crown expansion of mature trees. Although the disease survey is unlikely to detect all incidences of *Armillaria* fruiting and trees showing symptoms of ARD, more detailed follow up surveys suggest that the buffers do encompass neighbouring undetected infection (R. Robinson, unpublished). The results of continuing research on below ground incidence of ARD will also be used for future review and ongoing development of the survey method.

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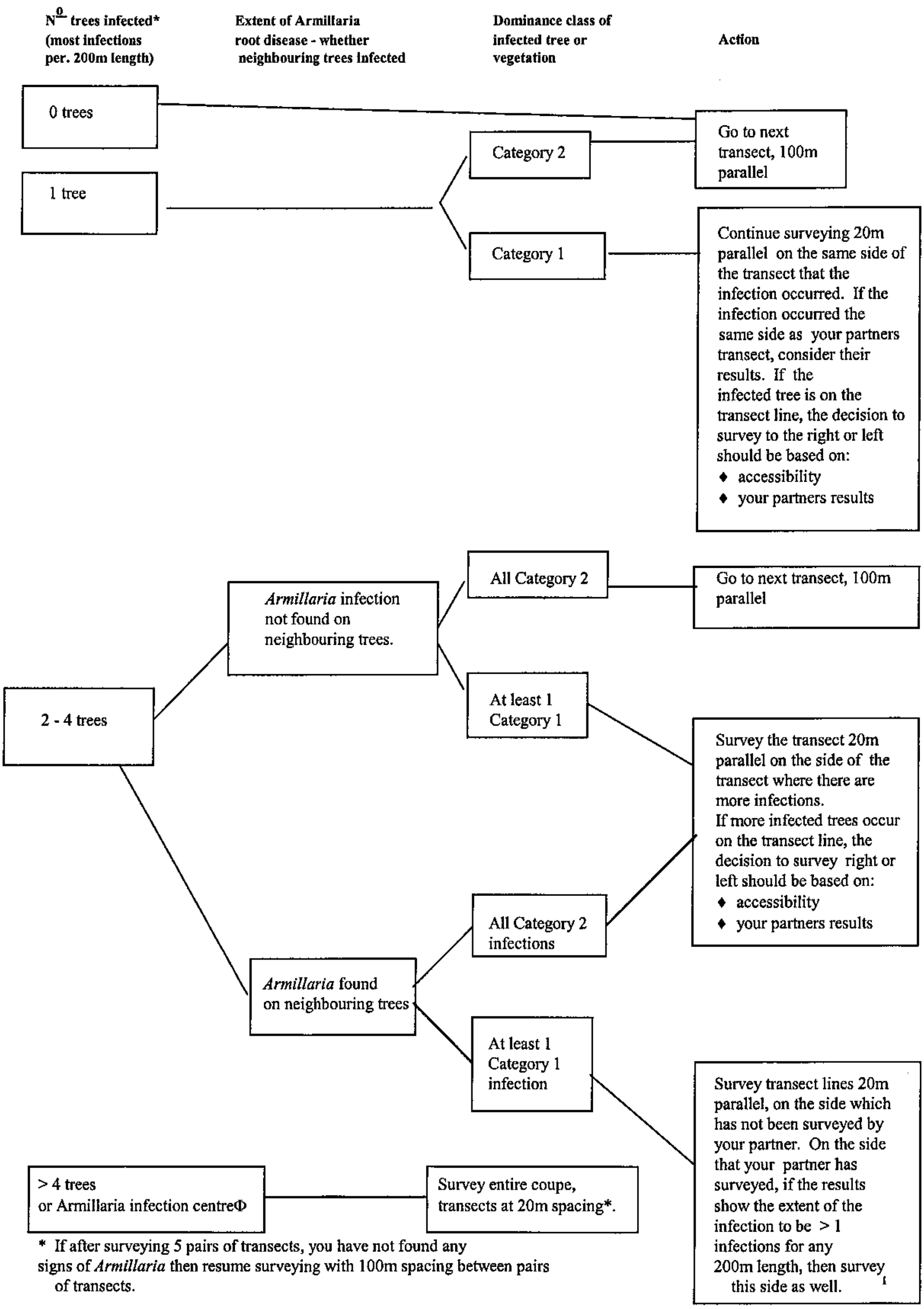
Armillaria Survey Guidelines



Φ Armillaria infection centre - a clearing resulting from several tree deaths due to *Armillaria* infection, where trees on the periphery of the clearing may be dead, dying or infected with *Armillaria,* and there may be windthrown trees within the clearing; **infected*** - based on *Armillaria* scars, fruiting bodies; **Category 1** is an infected dominant, co-dominant or subdominant tree; **Category 2** is an infected suppressed tree or understortey shrub, or *A. luteobubalina* fruiting on gruund.

APPENDIX 2. Draft *Armillaria* Survey Sheet

***Armillaria* Survey Field Data Sheet**

Coupe:
Date:
Assessor:
Transect Number:
Bearing:

Infection Site	**Distance**	**Number of trees infected at site**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1											
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Transect Summary - most significant *Armillaria* infection within 200m distance

No. of infected trees	
Category	
Adjacent transect to be surveyed?	Yes / No
Which side?	Right / Left / Both
Result: Transect number to be surveyed next	

APPENDIX 3. *Armillaria* survey map generated by Microstation95