INTRODUCTION TO THE DETECTION AND INTERPRETATION OF THE SYMPTOMS OF JARRAH DIEBACK DISEASE IN WESTERN AUSTRALIA

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FOREWORD

There have been three major advances in our knowledge of the extent of *Phytophthora cinnamomi* in the jarrah (*Eucalyptus marginata*) forest in Western Australia.

In 1965 the association of *P. cinnamomi* with dieback disease was determined.

In 1966 the ability to mark the broadscale extent of *P. cinnamomi* from 1:40 000 scale black and white aerial photos was developed.

From 1968 to 1978 the use of 1:4500 scale of 70 mm format, colour aerial photography to assist in detecting *P. cinnamomi* was developed into a practical system. This is a much more accurate method than that using 1:40 000 scale black and white photography.

With each advance in knowledge our previous attitude to dieback disease has to be adjusted. This Technical Paper will help us adjust to advances in knowledge gained using 70 mm colour photographs. It is based on several years experience interpreting and field checking by our interpretation teams, whose interest and dedication is acknowledged, together with that of the author of this paper, A. J. Brandis of the Inventory and Planning Branch of the Forests Department.

Only a relatively small proportion of the deaths in the forest of indicator species such as *Banksia grandis* are due to *P. cinnamomi*. This paper describes in simple terms the factors that assist an interpreter to decide which deaths are due to *P. cinnamomi*. An accurate map showing the extent of *P. cinnamomi* can then be prepared and this is crucial to successful management of a forest infected with dieback disease.

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SUMMARY

An accurate and reliable system for detecting dieback disease, based on full colour 70 mm aerial photography, has been developed. It includes field sampling and laboratory testing of soil and plant tissue and has enabled interpreters to carry out intensive and extensive investigations into the early symptoms of dieback disease. This paper shows that the results of the investigation programme provide a better understanding of the reliability and significance of deaths of particular indicator plants in interpreting the presence or absence of the disease over a wide range of forest types.

A summary of observation factors is included which should enable consistent and reliable decisions to be made. The observable factors are weighted in relation to the likelihood of the presence or absence of *Phytophthora cinnamomi*. By simply checking off the observations an interpretation relating to the likelihood of *P. cinnamomi* presence or absence can be made.

INTRODUCTION

It has been shown (Podger, 1972) that some plants present within the understorey of the jarrah (*Eucalyptus marginata Sm.*) forest are highly susceptible to *Phytophthora cinnamomi*, the cause of jarrah dieback disease. They can be used for detecting the presence of this disease in the early stages of infection. Some of the highly susceptible plants can be seen on 70 mm aerial photographs and identified as indicator species of the disease, and include *Banksia grandis* Willd., *Xanthorrhoea preissii* Endl., *Patersonia xanthina* F. Muell., *Xanthorrhoea gracilis* Endl., *Podocarpus drouyniana* F. Muell., *Persoonia longifolia* R. Br., *Macrozamia riedlei* (Gaud) C. A. Gardn.

The development of a full coverage, large scale system of aerial photography (Bradshaw and Chandler, 1978) now enables interpreters to detect and identify most understorey plants that have recently died. Establishing ground truth includes field sampling and laboratory processing of soil and plant tissue. The photographs allow repeated detection and identification of a particular dead plant and enable trained staff to locate that plant in the field. An example of the resulting map is shown in Appendix 1. The photographs also provide a means for accurately plotting areas of diseased forest onto 1:25 000 scale maps.

In 1978 a team of Forests Department interpreters began a programme aimed at the detection and mapping of jarrah dieback disease in State forest that had been proclaimed disease risk areas for at least 3 years. To June 1982, approximately 121 000 ha had been mapped using this system.

Early investigations were frustrated by a lack of knowledge of the many variables affecting the expression of the disease. It was therefore often difficult to determine whether an area was diseased or not. Apparent disease symptoms located on the 70 mm aerial photographs are checked thoroughly in the field to verify the photo-interpretation. This procedure is necessary to identify the observable factors that may have affected the site, and which may not appear obvious on the photographs. This paper describes the observations relating to the association and pattern of deaths that enable the interpreter to decide the most probable cause of death. This might be *P. cinnamomi*, or drought, fire, insect attack, competition, other pathogens, damage caused by machinery, or senility.

Sites investigated are recorded by a detailed description on a field sheet which includes relevant data such as vegetation, soil type, topographic situation, disease risk factors, disease pattern development, healthy and apparently disease affected plants and a film/frame reference. In addition to a detailed description of the site, soil and tissue samples are collected from recently dead, susceptible plants for laboratory processing to determine actual presence or absence of the pathogen *P. cinnamomi*. Appendix 2 is an example of a map showing where these field samples were collected.

METHOD

The initial detection, identification and plotting of the indicator species deaths (ISD's) from aerial photographs enables interpreters to group them into classes based on the dead species and the apparent association between the deaths. Four classes have been recognized (Figure 1), namely:

(1) Isolated ISD's - these are single dead plants that have no apparent association with any other death and may be within an area populated by many other healthy indicator plants.

(2) Scattered ISD's - these can vary from a single dead plant, to small groups of two or three dead plants. There may be many healthy indicator species between these scattered deaths which may occur over a wide area, and have no apparent association between the deaths.

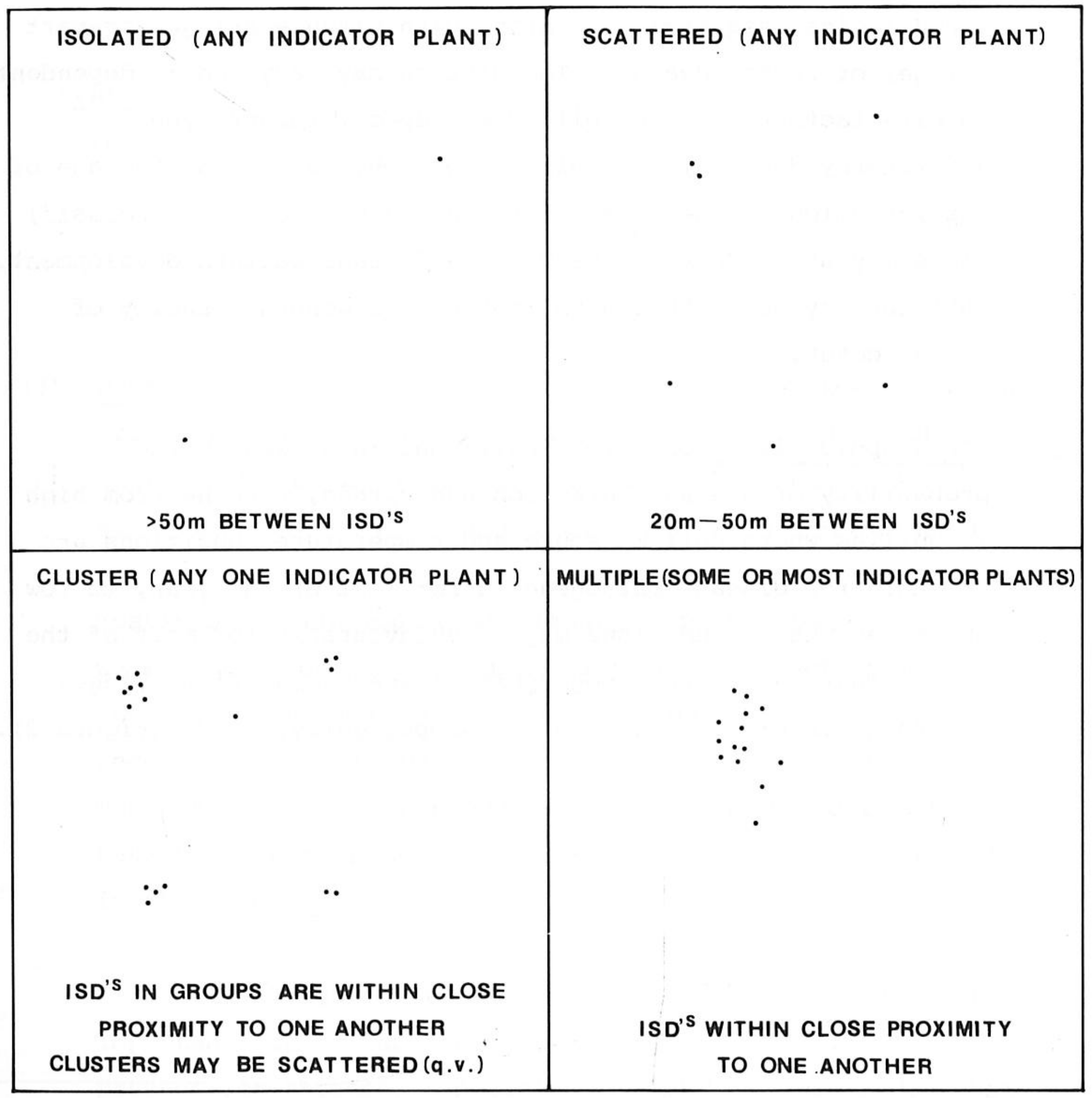
(3) Groups or Clusters of ISD's - two or more dead plants of the one species within close proximity of one another, with an

apparent association between the deaths, but discrete from other potential infections.

(4) Multiple ISD's - some or all the indicator species dead within the same area.

FIGURE 1

INDICATOR SPECIES DEATHS (ISDs) CLASSES
EACH OF THE FOUR SQUARES REPRESENTS 100 m × 100 m
EACH ISD IS REPRESENTED BY A BLACK DOT



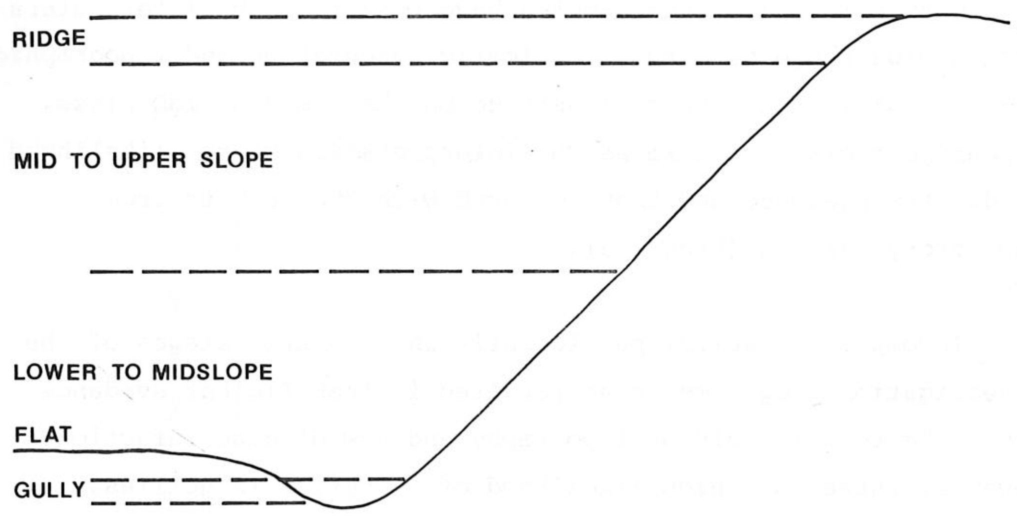
Other site factors such as topography, rocky and shallow soil, forest species composition, understorey density, roads and tracks and water gaining depressions can be observed using the 70 mm colour film. Some of these site factors may be more obvious from ground survey, and this can be verified when ground truth is established from field visits. The site factors of major relevance associated with the interpretation of disease presence or absence are:

(1) Pattern development amongst apparently affected indicator plants is perhaps the most important observation together with the ISD class. Disease pattern development is obvious by a chronological sequence of deaths, with often a fringe, or part fringe, of recent deaths. The pattern may vary and is dependent on site factors such as soil type, aspect, forest type, understorey density, rainfall, topography as well as the age of the infection. Some sites, for example blackboy (*X. preissii*) flats may have ISD's but very vague disease pattern development. Patterns may be further highlighted by a general paucity of ground cover.

(2) Topographic situations are significant in assessing the probability of disease infection and spread, ranging from high in gullies where soil moisture and temperature conditions are suitable for disease pathogenesis for most of the year, to low on ridges where conditions may be unfavourable for most of the year. There are five topographic classes identified, ridge, mid to upper slope, lower to mid slope, gully, flats (Figure 2).

FIGURE 2

TOPOGRAPHIC CLASSES



(3) Causal agencies. There is a high risk of disease infection from artificial agents such as road making and logging machinery that can transport inoculum over large distances. Such activities are readily observed. Risk of infection due to the natural spread of the fungus is less obvious, as spread is mostly by motile zoospores either in ground water or surface water. As each site is classified and recorded, samples including bark and wood tissue and soil are taken from the most recently dead indicator plant. Banksia is preferred as the most reliable indicator though reliable soil and tissue samples have been taken from all the indicator species listed earlier in this paper.

After weighting the observed factors for their relative importance as far as they influence the probability of disease presence or absence, a decision is made and recorded. Whenever necessary decisions are verified by the results from the laboratory testing of soil and tissue samples taken at each site.

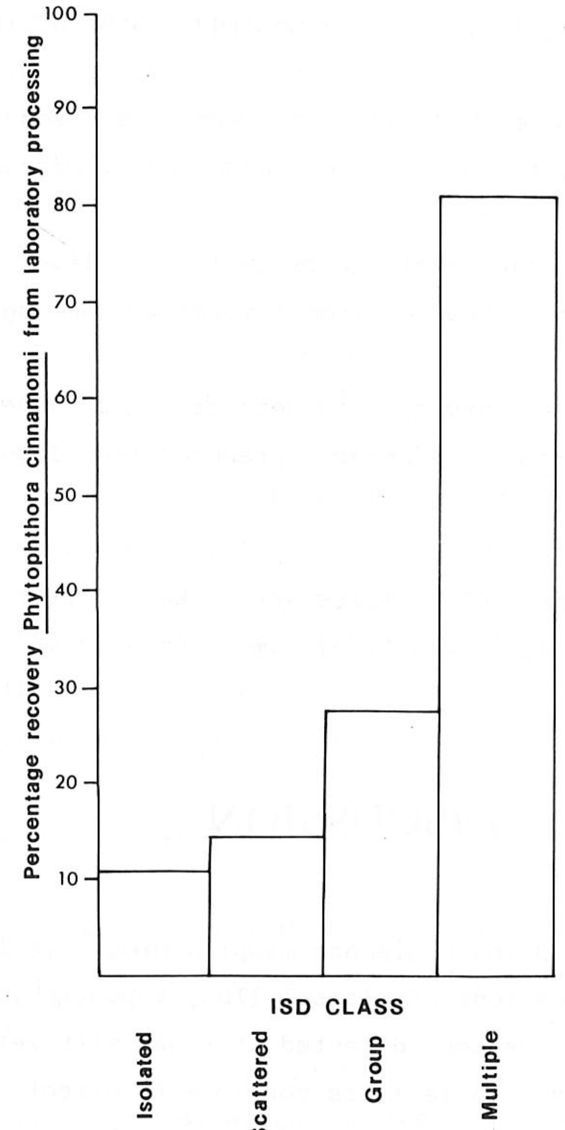
RESULTS

Many soil and tissue samples have been taken by interpreters from a wide range of edaphic, climatic, vegetation and topographical sites. Samples have been classified on the basis of ISD class, topographic class as well as the interpretation of the likelihood of disease presence and then compared with the results from laboratory testing (Figure 3).

Incomplete results, particularly in the early stages of the investigation programme, have resulted in insufficient evidence about the relationship of topography and new disease infection. However, there is a high likelihood of infection in gullies, ranging to low likelihood of infection on ridges. It has been observed that most *P. cinnamomi* infections occur in gullies and water gaining depressions. New infections are expected to be located mostly in the same topographical situation.

FIGURE 3

Percentage recovery of Phytophthora cinnamomi from samples within ISD class



Isolated class - 587 soil and tissue samples were collected in the field from sites classified as dieback-free, some suspect, with very few classified as dieback. Only 10.7 per cent of these samples had *P. cinnamomi* identified from laboratory testing. Those samples giving positive results were mostly classified as dieback or suspect and occurred near recent road making and logging activities. Isolated deaths of indicator plants that occur within healthy forest, and are not within close proximity to machine activity, are considered to have an extremely low likelihood of being caused by *P. cinnamomi*.

(2) Scattered class - 486 samples were collected, 14.6 per cent showed *P. cinnamomi* presence from laboratory testing.

(3) Groups or clusters - 990 samples were taken, 28.4 per cent of these samples showed *P. cinnamomi* presence from laboratory testing.

(4) Multiple ISD class - 606 samples were taken. After laboratory testing 81 per cent showed *P. cinnamomi* presence.

DISCUSSION

Results from the dieback disease mapping programme indicate that within the combinations of classes (ISD, topography, causal agent) investigations are best directed at those with weakest interpretation factors. While it is possible to direct the main effort of investigations towards these classes, they require soil and tissue sampling to verify interpretation. The group or cluster class in topographic situations other than the gully type, are the most difficult to interpret for *P. cinnamomi* presence or absence. Soil and tissue sampling is necessary in all classes, at least in the early stages of investigation, to determine whether any anomalies exist within a region given the relative importance of factors discussed here.

It has been found that disease expression can vary markedly within and between forest eco-types, for example, between the northern and southern jarrah forests. Southern jarrah forests have higher rainfall, are situated on different soils, with fewer *B. grandis*, lower mean soil temperatures due to dense understorey consisting of plants resistant to *P. cinnamomi* and therefore have fewer deaths of both the understorey and overstorey species. This contrasts markedly with the northern jarrah forest, where often dense stands of highly susceptible *B. grandis* can be dramatically affected and the entire stand of *B. grandis* may be killed and a large proportion of the overstorey may also be killed.

Death of susceptible plants within some forest areas are sometimes caused by factors other than *P. cinnamomi*. Most of these deaths cause interpretation problems when widely distributed and there is no alternative other than to take soil and tissue samples from a significant proportion for laboratory testing to determine whether *P. cinnamomi* is present or absent. Careful observations, documentation and interpretation of all sites is necessary to isolate the true manifestation of the disease.

Observations at field sites must be thorough as some disease situations (for example, wandoo (*Eucalyptus wandoo*) forest, southern jarrah) show scant biological impact. In these situations ISD's such as *Macrozamia riedlei* and *Xanthorrhoea preissii* should not be overlooked as they are important indicator plants.

A table showing the relative importance of field observations associated with photo interpretation for the presence or absence of *P. cinnamomi* is shown in Appendix 4. All factors must be considered within a continuum from high to low likelihood of the disease presence or absence. By weighting the observations, it is possible to make consistently accurate decisions of *P. cinnamomi* presence or absence. However, this guideline should not be considered infallible and soil and tissue samples should be taken to verify any interpretation. A thorough knowledge of the decision criteria gained from considerable field experience, is necessary before reliable weighting of the relevant importance of the observation factors can be achieved.

CONCLUSION

The dieback mapping group has been able to establish a logical procedure for the interpretation of dieback disease symptoms through disciplined observation and analysis of indicator species deaths, absolute locational and recording accuracy and a complete and improved *P. cinnamomi* sampling and identification procedure. The very high proportion of correct decisions made by the interpreters suggests that their procedures and the lessons learnt are worth adopting by anyone attempting to identify dieback disease in the field.

The decision guideline (Appendix 4) relates the experiences of the dieback mapping group and shows in a useful form the likelihood of arriving at a correct decision about the presence or absence of *P. cinnamomi* based on observation factors. The strongest indication of disease presence is the multiple ISD class with a development conforming to an obvious pattern combined with a topographical situation low in the landform profile. If observation indicates road making and logging operations have also taken place, this provides an even higher likelihood that dieback disease is present.

When combined with evidence from soil and tissue sampling this approach forms a sound basis for a decision making guide for jarrah dieback disease interpretation and mapping. Appendix 3 shows the resultant map.

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ACKNOWLEDGEMENTS

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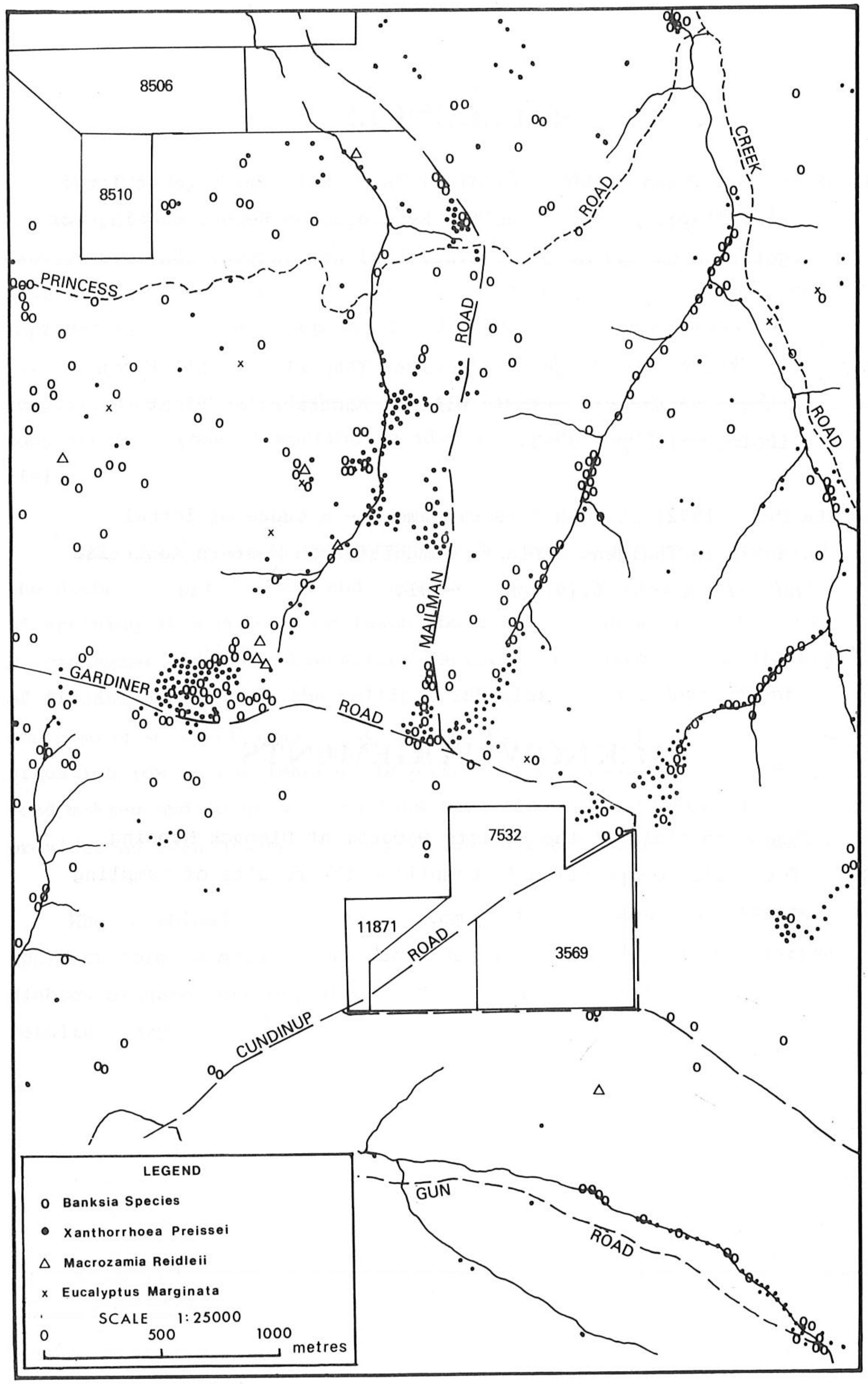
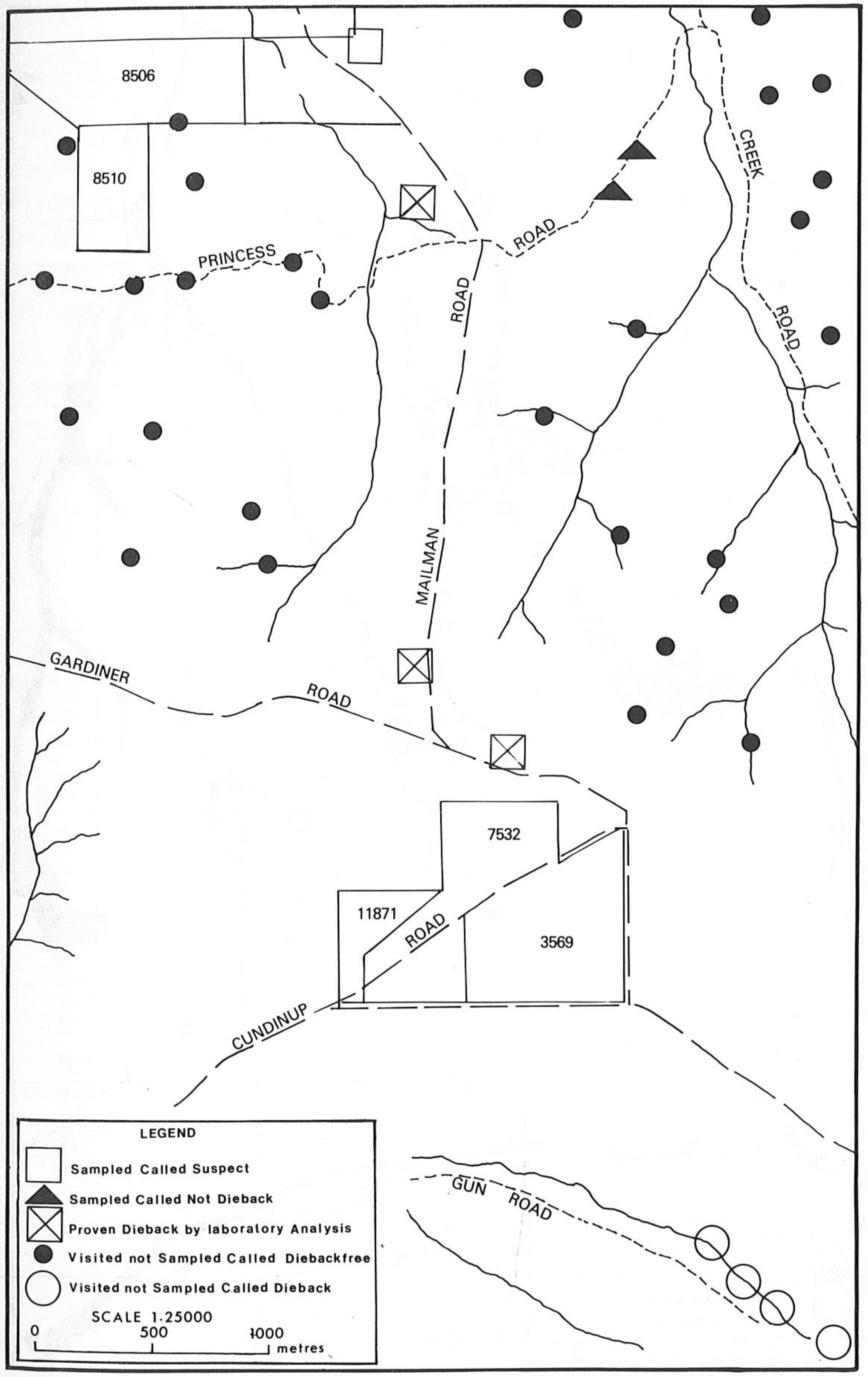


Appendix 1

ISD MAP

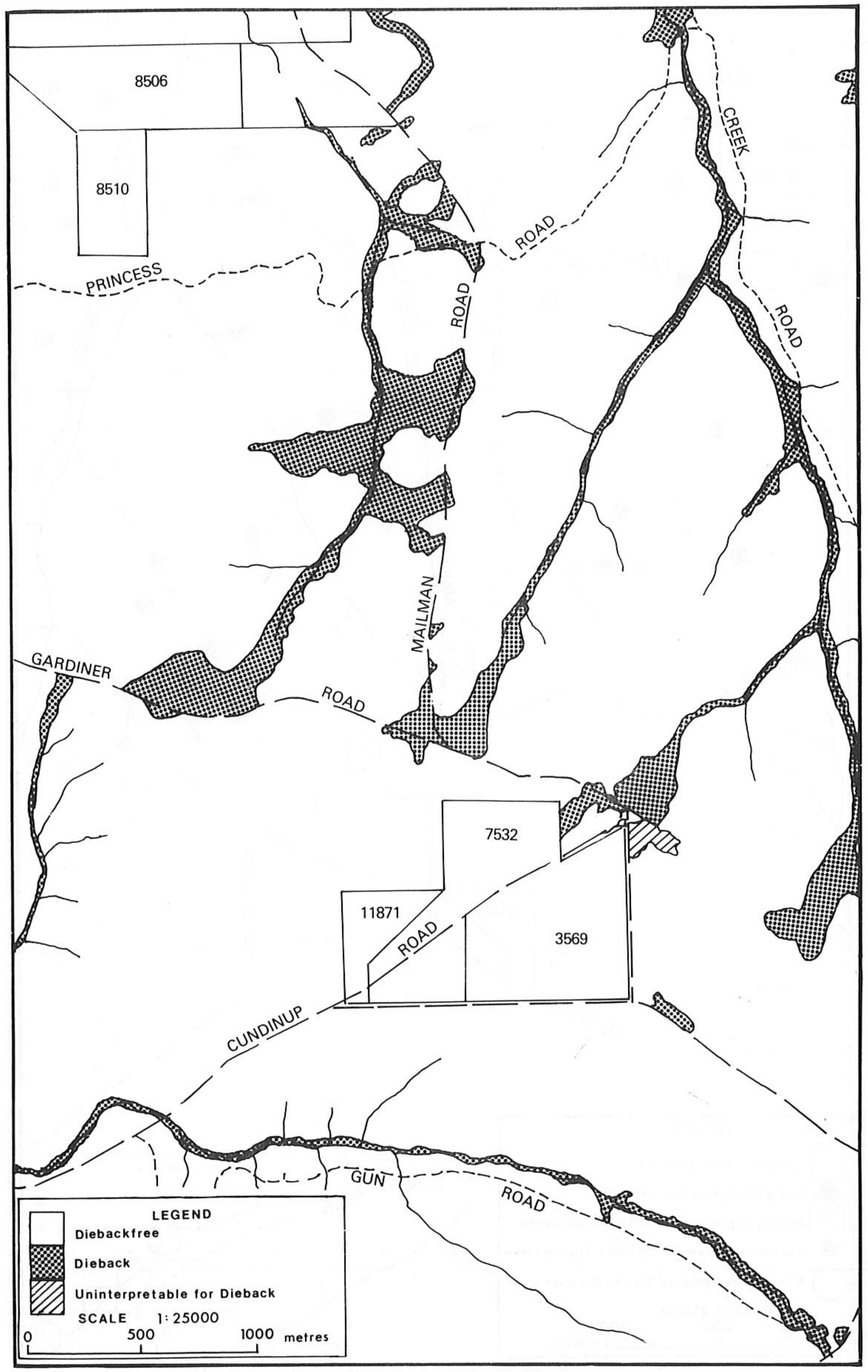
Example of portion of a map showing indicator species deaths as seen on 70 mm film.



Appendix 2

Field Sample Sites

Example of portion of a map showing where field samples of soil and plant tissue were collected for laboratory analysis.



Appendix 3

Location of *Phytophthora cinnamomi*. Example of portion of a map showing the location of *P. cinnamomi*. This map is prepared after the interpreter has evaluated his own field observations and the results of the laboratory analysis of soil and tissue samples of indicator species.

Appendix 4

Relative Importance of Observable Factors

Associated with the Interpretation for Presence or Absence of *P. cinnamomi*

	Observable factor indicating high likelihood of *P. cinnamomi* presence ◄	Observation Factors		► Observable factor indicating low likelihood of *P. cinnamomi* presence
ISD TYPE	Multiple ISD'S	Cluster	Scattered	Isolated
SPECIES	Some or most indicator plants	Any one indicator plant	Any indicator plant	Any indicator plant
PATTERN DEVELOPMENT	Obvious			Not obvious
TOPOGRAPHIC SITUATION	Gully/Flat	Lower to Mid Slope	Midslope to Upper Slope	Ridge
CAUSAL AGENT	Obvious			Not obvious
INTERPRETATION RESULTING FROM OBSERVATION:	High likelihood of *P. cinnamomi* Presence			Low likelihood of *P. cinnamomi* presence.
REQUIREMENT FOR SOIL AND TISSUE SAMPLE	Low Requirement For Soil and Tissue Sample	High requirement for Soil and Tissue Sample	High requirement for Soil and Tissue Sample	Low requirement for Soil and Tissue Sample