PROJECT 3

DEVELOPMENT OF GIS-BASED DECISION SUPPORT TOOLS AND THE DATABASING OF *PHYTOPHTHORA*-SENSITIVE TAXA

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1 INTRODUCTION

This document reports principally on the development of tools and methodologies to support dieback management decisions using expert knowledge and Geographic Information Systems (GIS). It also reports on the nature, accessibility and precision of relevant data sources held in Western Australia. A discussion of alternative management scenarios are included to illustrate the use of this approach.

Initially it was intended to develop decision-support tools for assisting the monitoring and control of dieback in the context of protecting *Phytophthora*-susceptible taxa[1]. A range of tools and approaches were developed which we believe will be of value to land managers. Since the inception of the project, utilisation of spatial analysis techniques has also evolved and this provided a valuable insight into the appropriate application of GIS technologies.

The acquisition and deployment of GIS hardware and software allowed the establishment of a range of spatial datasets relevant to dieback management. These included vouchered specimens of susceptible plant taxa and rare or threatened flora populations, dieback distribution data and associated environmental data. The process of integrating this

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[1] The notion of *susceptibility* is, at the very least, an ambiguous term. In this document the term is used to refer to those taxa *thought* to be susceptible in some way to *Phytophthora*. It does not imply any statements as to the specific nature of that susceptibility.

information is described together with some implications for data management within the Department.

A later phase of the project attempted to evaluate the utility of developing a predictive model of the movement of dieback, based on known biological constraints and environmental responses of the pathogen. This phase focused on an area of Western Australia (Two Peoples' Bay) for which considerable dieback data were available. A GIS prototype was developed to display the outcome of the model. Subsequent assessment of this approach showed clearly that, while having potential value, it would place an unacceptably great demand on computational resources. Moreover, the diversity within native plant populations, the presence of complex substrate mosaics which affect soil hydrology (and hence dieback progression) and the complicated interactions between these factors render accurate modeling of predicted dieback movement difficult if not impossible.

The most recent phase of the project employed an expert systems approach which had more realistic requirements for data and computational resources while providing a flexible decision-making environment for managers. The term "expert systems approach" is used here in two ways. Primarily it refers to the expert selection of criteria for evaluating a range of threats to taxa, or different management options. It also refers to the preferred use of simple or stylised models of physical qualities (e.g. soil type or rainfall) rather than models of complex qualities or processes such as the rate of zoospore movement through subsurface soil channels. In this project we are not dealing with the more common understanding of the term to represent expert system shells or the various modes of encapsulating expert knowledge in a particular computing language. Applications of this expert systems approach are described. These include the overlaying of dieback distribution with susceptible flora populations. Some of the consequences of the spatial relationship between dieback and susceptible taxa, and implications for management, are also considered.

2 OBJECTIVES

The objective of this work was to develop reliable graphical decision-support tools for monitoring and controlling the spread of dieback[2] disease. This required:

- evaluation of the role of GIS and the processing of spatial information in land management decision-making in relation to problems arising from the invasion of native vegetation by *P. cinnamomi.*

- evaluation of relevant spatial data sources and their quality for use within land management decision-making.

3 METHODS

An inventory of dieback distribution data was conducted within the Department of Conservation and Land Management (CALM). The extent and currency of the data were assessed together with accuracy statements (if available) pertaining to the location of dieback-affected vegetation and the identification of causal factors or agents. Staff were interviewed from each CALM administrative region where information on dieback distribution might be available. These included Greenough (Moora District), Swan, Central Forest, Southern Forest and South Coast Regions. Research scientists from CALM's Science and Information Division were also interviewed.

Dieback distribution data were obtained from various sources including point, line, polygon and grid cell, or digitised from map products where these were the only available source. Point locations of threatened and priority flora populations were sourced from CALM's

[2] In this document, the terms *dieback* and *Phytophthora* are used, though not interchangeably. Dieback refers to the expression of a disease which may or may not be associated with a pathogen such as *Phytophthora* spp. Certain datasets used in this project, document tree deaths, as interpreted from aerial photographs or ground stripping. The term dieback is used in relation to these datasets. References to the distribution of explicitly identified isolates of *Phytophthora* spp. are denoted as such.

Threatened Flora Data Management System, an Oracle database. These were added to the vouchered herbarium specimen records of susceptible taxa already obtained in the initial phases of this project.

All data were converted from existing formats into Arc/Info™ coverages. In some cases data were already in a digital format such as Microstation™ design files or tables in word processing documents. In other cases only paper maps were available and these were digitised. All processing and analysis was conducted with Arc/Info™ V7.0.4 (TIN and GRID options) on a Sun Microsystems™ Sparc 10.

To generate a single polygon coverage of dieback distribution, data were reclassified to have a consistent coding scheme. Grid and polygon coverages were examined for accuracy and consistency (e.g. overlapping polygons). Where dieback was represented as points and lines, these were buffered by arbitrary amounts to represent area. For example, lines were buffered by 10 metres on the assumption that dieback was assessed from a roadway (itself accurately represented in digital format) which afforded only partial visibility of the area affected by dieback. Points were arbitrarily buffered by 200 metres in the absence of any knowledge of area of impact.

A Euclidean distance grid was generated for the resultant coverage. For each cell, this grid recorded the distance to the nearest (linear) location of dieback. For each flora population, the corresponding distance was calculated from the distance grid. The populations were then classified according to distance from nearest dieback and symbolised accordingly.

3.1 INVENTORY AND COLLATION OF EXISTING DIEBACK DISTRIBUTION DATA SOURCES

Dieback distribution data were obtained from a number of sources (Table 1). These data have been obtained for a variety of purposes over some 30 years during which technology of data capture and understanding of the nature of the problem have undergone continual change. Each of these was evaluated for accuracy, consistency and suitability for use in a decision support system for managing the problems associated with the presence of pathogens such as *Phytophthora* spp.

Table 1. Dieback distribution data.

Source	Type	Number of dieback polygons or points
FMIS (Combined pre- and post-1976)	Polygon	13,076[3]
Swan Region	Polygon	561
Central Forest Region	Polygon	157
South Coast Region	Polygon	83[4]
Vegetation Health Service	Point	2432
Swan Coastal Plain Study	Point	46
Northern Sandplains	Point	87

3.1.1 Forest Management Information System (FMIS)

FMIS is a grid-based data management system, with cells normally 140m x 140m. FMIS is used by Forest Management Branch as a management and reporting tool for forest operations in southwestern Australia. One of the datasets maintained within FMIS is dieback distribution. While some comments will be made below regarding the accuracy of dieback distribution data held within FMIS, it is important to note that these data are too coarse for use in day-to-day operations by field staff.. The primary use for the data is an aid to regional planning.

Sources for dieback distribution data include assessments from aerial photography and ground stripping. Historically, cells were manually coded into FMIS from paper maps. More

[3] Data from the Swan and Central Forest Regions are warehoused in FMIS and may artificially increase the polygon count for FMIS.

[4] Only broad-scale information was available for the South Coast region during this project. Finer level operational detail exists but was not available at the time of writing.

recently, distribution maps have been maintained within desktop CAD packages and then imported directly into FMIS.

Prior to 1976 a major project resulted in the compilation of a statewide map of dieback incidence. Three categories were defined: dieback present, dieback suspect and dieback absent, the assumption being that the predominant cause of dieback was *P. cinnamomi*. The interpretations have since been found to over-estimate the actual extent of infected areas due to mis-diagnosis of cleared land or tree deaths. Distribution data were manually coded into FMIS from paper maps.

Since 1976, dieback distribution data have continued to be either directly coded into FMIS from paper maps or warehoused from separately maintained vector databases using higher resolution aerial photography and ground stripping. Updates on dieback assessment are made on the basis of proposed logging operations in a given area.

3.1.1.1 Data Accuracy

While FMIS provides the most comprehensive digital repository of dieback distribution for the jarrah forest and surrounding areas, there are a number of characteristics of the data processing that impact on its reliability and comprehensiveness. Historically, data were coded manually into FMIS from paper maps and here, subjective judgements were made as to how certain features were coded (e.g. narrow, linear polygons). In some cases, features were distorted to maintain consistent area statements, though the resultant feature might become jagged or discontinuous. Manual coding of FMIS data was an operator-intensive process requiring a high degree of training and experience. Consequently, the likelihood of coding errors increased.

More recently, data from separately maintained vector databases are regularly warehoused in FMIS. The conversion process from vector to FMIS grid cell utilises a centre-point approach. That is, grid cells will only be coded if a vector polygon passes through the grid centre-point. While this might be an acceptable approach for large polygons, it can produce errors in polygons with a narrow or linear morphology as may be the case with dieback distribution. It is also possible that certain infections could be missed altogether in the conversion process.

An initial intention of the present project was to provide a comprehensive statement on the distribution of dieback in southwestern Australia. However, combination of all available databases to produce a map of disease distribution would have included sources where diagnoses were probably inaccurate and it was felt that the resultant map would be a misleading document. Accordingly, the maps in this report have been sited over areas where the FMIS distribution data were known to be relatively accurate. Areas west of the forest regions were known to be significantly less accurate than within the forest regions. Additionally, no area statements have been included, again because of questionable accuracy.

3.1.2 Vector Databases

Dieback distribution data have been maintained by Swan and Central Forest Regions for the last few years within a Microstation™ environment. Categories include dieback confirmed, suspect and free. Additionally, hygiene categories are coded as well as *Armillaria* and other species where area of distribution is within a radius > 30 metres. Recently, Southern Forest Region has commenced digitising dieback distribution data rather than manually coding into FMIS.

3.1.2.1 Data Accuracy

The spatial accuracy of dieback polygons within the vector systems has been described by regional staff as very high (±10m). However, spatial problems were noted when combining data from multiple files. These usually involved overlapping polygons between adjacent maps and inconsistent or inappropriate attributing of polygons. Generally, these kind of errors occur when there is an overall emphasis on cartographic output rather than topological correctness, an essential prerequisite for spatial analysis.

3.1.3 South Coast Region

Until the initiation of this project, no digital data were available for dieback distribution in the South Coast Region. Sources of spatial distribution information comprised two categories: those used at an operational level and maintained at a high degree of accuracy, and those used at a broad or regional scale and maintained at a relatively low degree of accuracy. Unfortunately, only the latter were available during the course of this project. Broad scale maps were generally maintained at scales of 1:100,000 or 1:250,000.

3.1.4 Vegetation Health Service

The Vegetation Health Service (VHS) maintains a Paradox database of identifications of soil and/or plant samples for particular pathogens. Each sample is received in a plastic bag and given both a unique identification and a bar code number to assist in handling. Samples are generally assayed (i.e. flooded and baited with *Eucalyptus sieberi*) to detect and identify *Phytophthora* spp. and the results stored in the database. These samples may contain soil or plant material or a mixture of both and the resultant identification is one of association. Where requested, plant material is surface sterilised and tested. These results are stored separately.

3.1.4.1 Data Accuracy

The database was examined to evaluate its incorporation into the project. While the identifications themselves were performed according to strict standards, a number of issues arose regarding the numbering and geocoding of identifications including non-unique identifiers, a multiplicity of coordinate systems and the lack of spatial accuracy statements. Of 12,000 records in the VHS database, only 7,000 contained sufficient spatial data for incorporation into a GIS environment. Of the latter, a number were found to be inacccurate and these were excluded from the maps.

3.1.5 Swan Coastal Plain Study

Data sources were limited to the Swan Coastal Plain in areas of dying *Banksia* woodland in national parks and reserves (Shearer & Dillon, 1996). They were stored in a word-processing document and converted to a GIS coverage. There is no statement as to the spatial accuracy of the sites in this study, though each was recorded within a nature reserve or national park.

3.1.6 Northern Sandplains Database

Point locations of dieback pathogen isolates in the Moora District (Greenough Region) are maintained by a private company, CRA. These points were available to this project subject to approval from the Northern Sandplains Dieback Working Party. The spatial coordinates are derived from a GPS and are stated to be accurate to ±100m.

3.2 THREATENED/PRIORITY FLORA DISTRIBUTION

Point locations of threatened/priority flora populations were extracted from two sources and converted into a point coverage. Sources were the Western Australian Specimen Database (WAHERB) and the Declared Flora Management System (DEFL). Only taxa belonging in *Myrtaceae*, *Proteaceae*, *Epacridaceae* and *Papilionaceae* were extracted. These families were chosen because they contain the highest proportion of susceptible taxa. Points from WAHERB had a mixed spatial accuracy ranging from seconds of arc to many kilometres. For points from DEFL, spatial accuracy is regarded as generally high by the data custodian, due to the requirement to revisit sites (within 150m). However, there were indications of considerable variation in the degree of accuracy for certain points and these were excluded from subsequent maps and analyses.

4 RESULTS AND DISCUSSION

Key objectives of this project were to evaluate both the role of GIS and the quality of relevant spatial data sources for use within land management decision-making in relation to problems associated with *Phytophthora*.

All major data sources within CALM were collated and analysed to illustrate how GIS can address some of the land management problems associated with dieback. These data sources were used within a number of applications of great potential value for land managers. Where these applications are considered sufficiently valuable, issues regarding data accuracy, quality and currency must be addressed as a prerequisite to use of the data to support management decisions. Equally important, protocols for the use of decision support tools should be developed for regional operations managers concerned with dieback.

4.1 POSSIBLE APPLICATIONS

If suitable and relevant information is available, a number of land management applications become possible to assist in the management of problems associated with *Phytophthora*. The applications described below are only a sample.

4.1.1 Location of Disease

A fundamental question to addressing many of the problems associated with *Phytophthora* is "where is the disease?". It impacts on setting priorities for conservation measures, hygiene operations, assessing threats of extinction, projecting the yield of natural products and managing to slow progression of disease into healthy areas. If knowledge of disease occurrence is unavailable, the likelihood of fresh outbreaks is increased and limited management resources may not be applied effectively.

There are a range of costs associated with collating an accurate picture of dieback distribution and these vary according to the method adopted for documentation. For example, recording disease boundaries requires greater spatial accuracy, more data and information on currency than recording only the centroid of a diseased area.

However, a comprehensive distribution map would offer a number of advantages to managers. As one example of a distribution map, point data were used to give an indication of the distribution of *P. cinnamomi*. Points from the VHS and the Northern Sandplains Database were used. These data represent positive isolations of *P. cinnamomi* and are shown in Figure

1. It is notable that the map was generated from a subset of points from the VHS database and does not necessarily indicate the total distribution of the fungus. The locations from which isolates were obtained range from Eneabba in the north to Hopetoun in the east and are limited to areas receiving greater than 400mm average annual rainfall. At first glance the map would seem to indicate a high density of isolations in the forest regions, with smaller clusters in the Two Peoples' Bay area, Stirling Range National Park and Moora District and scattered points elsewhere within the 400mm isohyet. The high density of points in the forest area is partially explained by the mandatory requirement for dieback assessment prior to logging operations.

One potential application of these data is to generate a distribution model based on climatic values using programs such as BIOCLIM or CLIMEX. By developing a climatic profile for *P. cinnamomi* based on a range of seasonal rainfall and temperature statistics, areas of potential distribution (currently unconfirmed) would be indicated. This would allow a more effective direction of survey effort.

4.1.2 Conservation Issues for Threatened and Priority Flora

Another useful application of GIS technology is to display the distribution of a pathogen such as *P. cinnamomi* in the context of threatened flora thought to be susceptible to dieback disease. Figure 2 shows the data from Figure 1 overlaid with the distribution of threatened and priority flora populations. Only species belonging in *Myrtaceae*, *Proteaceae*, *Epacridaceae* and *Papilionaceae* were selected for display as these families appear to comprise the majority of taxa considered to be highly susceptible to *P. cinnamomi*.

It is interesting that threatened and priority flora populations have a fairly even distribution throughout most areas of the south-west and wheatbelt, with the exception of the forest regions. This appears to be an accurate reflection of population distribution for the four families noted above, and it is not an artefact of inadequate sampling. The map (Figure 2) indicates areas of concern where threatened flora and *P. cinnamomi* are coincident. These include the Stirling Range National Park, Two Peoples' Bay area, and Beekeepers and Lake Logue Nature Reserves. While much attention has been focussed on the impact of *P.*

cinnamomi in the forest regions, this map shows that the real areas for concern lie elsewhere, particularly in the South Coast Region and the Northern Sandplains where many populations of threatened, susceptible flora are in immediate danger from *P. cinnamomi*.

4.1.3 Priorities for Resource Utilisation/Management Options

Where resources for managing the problems associated with *P. cinnamomi* are limited, it becomes necessary to set priorities for the use of those resources to ensure that areas in greatest need of management receive appropriate attention. GIS technology can be used to identify and classify a range of environmental factors which may suggest alternative management options for flora. For example, those populations in close proximity to *Phytophthora* (either linearly or through a drainage network) are in immediate danger. The best currently available approach is spraying with phosphonate which is an effective but costly fungicidal treatment to provide temporary protection. The advantage of identifying the closest plant population to a known *Phytophthora* infestation is that it provides a consistent, objective and logical basis for setting priorities in regard to utilisation of a limited resource, namely phosphonate.

Alternatively, populations could be identified for "protectability". Here, plants at a sufficient distance from *Phytophthora* to be safe from infection via drainage or autonomous spread of the organism, may yet be in danger from other vectors. A different management regime might then be warranted. For example, hygiene procedures that prevent or minimise the possibility of accidental infection.

A map discriminating between populations simply on the basis of linear proximity to *Phytophthora* provides a crude but useful mechanism for managers to apply appropriate intervention in a more efficient and effective way than an *ad hoc* approach. Although *Phytophthora* is largely disseminated along hydrological channels, it has already been determined that modeling this kind of movement is impractical. Figure 3 depicts threatened flora populations according to linear proximity to dieback. This map incorporates all available dieback information. No distinction has been made as to the actual pathogen. The map extent was selected on the basis that all of the dieback sources were known to be relatively accurate in this area, and there were a number of flora populations with a range of indicated management scenarios. Figure 3 clearly discriminates between points which might be candidates for phosphonate spraying, those which might warrant fencing or other hygiene measures and those which are far enough away to warrant no specific action in relation to *Phytophthora*. Control options may be modified according to any existing measures in place as a result of land tenure. For example, points displayed within existing conservation areas may already be fenced. Figure 3 may help to identify those points not already subject to control.

4.1.4 Application of Further Expert Criteria to Improve Priority Setting for Resource Utilisation and to Identify Future Problems

As stated previously, the objective of this project has been to develop tools and methodologies that can provide managers with a range of options for dealing with problems associated with dieback. Where possible, we have focused on the application of existing expert knowledge of those factors which affect the location, spread and impact of *Phytophthora* spp. particularly *P. cinnamomi*. Factors recognised by experts to affect the distribution and activity of *Phytophthora* include soil moisture and soil temperature. Experts have also recognised that the impact of *Phytophthora* on any given host species will vary both within and between species. It is possible to draw together fragmentary information on these factors in a manner which utilizes existing, relatively inexpensive data, yet provides available information for managers.

Some examples of this approach are shown in Figure 4 which maps the distribution of four species of *Banksia*, a genus generally considered to be highly susceptible to *Phytophthora*. These distributions are overlain with average annual rainfall isohyets and with the Spearwood dune system (this latter boundary is very approximate but serves to illustrate the application) which has no record of the occurrence of dieback. Average annual rainfall was chosen in recognition of the known limitations of *Phytophthora* to areas receiving more than 400mm average annual rainfall. Combining these two layers, with the distribution of particular species, can provide an indication of the threat of extinction to those species.

Whilst the use of rainfall and the Spearwood dune system may appear crude, they nevertheless provide managers with information that could improve the application of resources in managing dieback. With the use of expert knowledge, other layers such as temperature and land tenure may be similarly employed to provide a more detailed or finely tuned range of preferred management options.

Banksia attenuata ranges from the Murchison River to Bremer Bay, almost totally within the 400 mm isohyet. In a worst case scenario, where the entire distribution was affected by *Phytophthora*, it would become restricted to some small wheatbelt locations as well as those coastal locations in the Spearwood dune system. Thus, whilst *Phytophthora* might dramatically reduce the total distribution of *B. attenuata*, it does not represent a threat to the complete extinction of this species.

B. brownii is known from 18 populations restricted to a small area from the Stirling Ranges to Albany and east to Cheyne Beach. At least two populations of this species are already extinct due to the pathogen. All known extant populations are infected with *P. cinnamomi* and are within the 400 mm isohyet. This species is therefore highly vulnerable to *P. cinnamomi* and warrants the application of phosphonate to prevent its imminent extinction.

B. cuneata also has an extremely limited distribution but most, if not all populations lie outside the 400 mm isohyet. With the exception of the most southerly population all populations are free of infection. This small population, in remnant vegetation surrounded by extensive land clearing, occurs on a water gaining site suitable for *P. cinnamomi* which has already caused the death of a number of plants. A protection strategy of tree planting to reduce the ground water table coupled with phosphonate treatment has been implemented.

In contrast to the three previously mentioned *Banksia* species *B. elderana* occurs entirely outside the 400 mm isohyet range and in areas where *P. cinnamomi* is unlikely to ever be a threat.

4.2 DATA SOURCE QUALITY AND IMPACT ON USE WITHIN A DECISION SUPPORT SYSTEM

Dieback distribution data have been acquired from a number of sources for this project. Depending on the required accuracy and timeliness of these data sources, the cost to maintain them can range from considerable to prohibitive. The accuracy and timeliness of the data depend on the criteria used by managers and experts in their decision making and hence the resource applied to their maintenance.

However, it is *not* a foregone conclusion that dieback distribution data *should* be maintained on an ongoing basis. It *may* be possible to implement a decision support system that does not utilise dieback distribution data. For example, using relevant biophysical data such as rainfall to determine management options and priorities as exemplified in Section 4.1.4.

In the event that dieback distribution data (or any data for that matter that are associated with managing dieback) are considered sufficiently important to maintain, a number of important factors should be considered.

4.2.1 Data Integration and Importance of Standards

In assembling the data the importance of maintaining it in a consistent fashion became clear. Because dieback distribution data are currently maintained independently across a number sites, it is inevitable that differences in coding schemes will develop. If the data are destined to be warehoused in a single coverage for use in a decision support system, then steps must be taken to ensure standards in spatial and textual data entry.

One consequence of this is that each area responsible for maintaining dieback distribution data should be trained to utilise the same software tools. It goes without saying that each area should have access to these tools.

By its nature, warehousing introduces a time lag between the live data and the warehoused data. Because of the dynamic nature of dieback distribution data, it is also important that protocols be established for the timely updating of information.

5 OUTCOMES

5.1 SINGLE REPOSITORY FOR DIEBACK DISTRIBUTION DATA

Hitherto, dieback distribution information has been stored in a variety of formats both throughout the Department, and externally. For the first time, most of these datasets have been brought together into a single coverage. While the data have varying degrees of accuracy and currency, they provide managers with a comprehensive, broadscale view of dieback distribution, comprising the best distribution data available.

5.2 DATABASING OF *PHYTOPHTHORA*-SUSCEPTIBLE TAXA

Because of the dramatic consequences of *Phytophthora* for native vegetation, any decision-making regarding its management and control should be supported by the best available information on those taxa most likely to be affected, directly or indirectly, by the pathogen. This project has resulted in the complete databasing of voucher specimen data for sixteen putatively susceptible plant families (Shea, 1991) and population data from the *Myrtaceae*, *Proteaceae*, *Papilionaceae* and *Goodeniaceae*.

5.3 THE ROLE AND POTENTIAL APPLICATIONS OF GIS TECHNOLOGY

One of the key objectives of this project was to evaluate the role of GIS in assisting the decision-making process for land managers in relation to the problems associated with dieback. It is clear from the results of this work that utilising GIS technology is the only way to effectively manage and analyse quantities of data on a statewide scale as well as documenting information at a highly detailed level (where such information is available).

A number of potential applications of GIS technology have been demonstrated. Each application has relied on simple visualisation techniques to provide managers with relevant information for determining resources and priorities. With little difficulty, managers can classify flora populations into categories suited to different management options such as those requiring phosphonate spraying, or those best suited to fencing.

However, the deployment of these techniques is not a foregone conclusion. Application of GIS technology is dependent on managers recognising its potential is assisting the decision making process. More importantly, it is dependent on managers learning to ask new questions; questions that in many cases could not be answered manually or through the use of traditional textual databases.

The use of GIS technology in land management at an operational level is still relatively new. Because of this, many managers are suspicious, or at least sceptical, of seemingly hi-tech applications which require a variety of complex and expensive inputs and then churn out a solution. One important outcome of this project has been to demonstrate the need for simplicity and transparency.

Rather than employing complex process models of the spread of *Phytophthora*, very simple spatial analysis techniques can be used to set priorities for the application of limited resources in the most effective manner. The key to their success, however, is in the expert selection of relevant criteria to manage the disease. Managers are most likely to adopt these techniques if they are transparent and readily understandable.

5.4 PROTOCOLS

Clearly, if the approach outlined in this report is recognised as being useful to experts and/or land managers: (*a*) in providing a central point of access to current dieback-related and environmental datasets; (*b)* in providing a focus for debate, discussion and decision-making on potential management scenarios ; and (*c*) in operational planning and implementation of disease control, then a set of protocols for the use of the decision support tools must be developed:

- for the maintenance and integration of relevant datasets;
- for the application of expert knowledge and the ways in which the validity of data will be interpreted;
- to ensure availability of the most up to date data and tools throughout the administrative system.

6 REFERENCES

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CONTROL OF *PHYTOPHTHORA* AND *DIPLODINA* CANKER IN WESTERN AUSTRALIA

FINAL REPORT

TO THE THREATENED SPECIES AND COMMUNITIES UNIT, BIODIVERSITY GROUP ENVIRONMENT AUSTRALIA

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