# **SCOPE ITEM 3**

# DEVELOPMENT OF PROTOCOLS FOR PRIORITY SETTING IN MANAGEMENT SYSTEMS ESSENTIAL TO THE PROTECTION OF NATIVE BIOTA THREATENED BY PHYTOPHTHORA

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# 1 INTRODUCTION

This report describes an approach to the development of protocols for management of *Phytophthora*-sensitive vegetation, with particular emphasis directed towards the evaluation of any threat of extinction posed by the pathogen to taxa of native plants.

Details of other approaches to the management of disease caused by *Phytophthora* in native vegetation were provided in earlier progress reports. Wills & Chapman (1993) proposed the development of Geographic Information Systems (GIS)-based tools for predicting the distribution of *Phytophthora*. The shortcomings of this strategy were highlighted by Gioia *et al.* (1997) who suggested an alternative, expert systems approach that did not attempt to model the physical behaviour of *Phytophthora* in the natural environment. The current work further utilises the expert systems approach to provide a methodology for the development of simple protocols that can be readily assimilated and used by planning or operational staff for managing threats of extinction to native flora.

Gioia et al. (1997) discussed the potential role of GIS in assisting land managers to prioritise deployment of resources for management of problems arising from the presence of *Phytophthora cinnamomi* in native plant communities. More specifically, examples were generated to illustrate how managers might set priorities for application of phosphonate (fungicide) to threatened plant populations based on the proximity of confirmed *Phytophthora* infestations.

Although rare or threatened taxa are of obvious concern, and have been ranked accordingly for the allocation of available resources, less attention has been paid to the potentially widespread destruction of some common species. An example is *Banksia grandis*, a species known to be highly susceptible to *P. cinnamomi*. While widely distributed in the jarrah forest, *B. grandis* is almost completely restricted to high rainfall zones where conditions are relatively favourable for establishment of *P. cinnamomi*, at least when soil moisture and temperature levels are conducive to production of infective spores.

Currently, there is no cost-effective treatment for the control of *Phytophthora* on a broad scale. In a hypothetical worst case scenario, the eventual spread of the pathogen might be expected to occur throughout its preferred environment. If so, a widespread species such as *B. grandis* could be under threat of extinction.

Therefore, land managers must consider not only taxa with restricted populations, but also comparatively common species in vulnerable situations such as that illustrated by the worst case scenario referred to above. Clearly, a protocol designed to evaluate threats of extinction would assist managers to determine if complete loss of a species might be expected, or whether some reduction in its distribution was a more likely and less significant outcome. A rational allocation of control resources would thus be facilitated.

The methodology for developing such a protocol is described here. The protocol was based on expert knowledge in combination with GIS decision support tools. This involved a series of detailed interviews with an acknowledged expert on the pathology and management of *Phytophthora* and the disease it causes. GIS technology was used to assemble various data layers pertinent to the vulnerability of sensitive taxa and to visualise combinations of these layers so that a logical set of criteria could be applied to assess the threat of extinction for individual taxa. Through simple visualisation and exploration of relevant GIS layers, expert knowledge was formulated into a series of steps for assessing the threat of extinction.

# 2 OBJECTIVES

The purpose of this work was to develop methodology for the generation of a protocol to assess threats of extinction posed by *Phytophthora* to native plant taxa and, thereby, to assist priority setting in management systems essential to the protection of indigenous biota under existing or imminent threat from the pathogens.

# 3 METHODS

Three genera that included *Phytophthora*-sensitive species were selected initially to provide test cases for developing a protocol for assessing threats of extinction to native taxa. These were *Banksia*, *Darwinia* and *Xanthorrhoea*. However, work on the last two of those genera was discontinued at an early stage when it became apparent that adequate datasets were unavailable. Moreover, it was considered that scenarios associated with selected *Banksia* spp. would be sufficient to develop a comprehensive protocol relevant to most situations.

Data were initially acquired from the Department of Conservation and Land Management (CALM) Herbarium specimen record database (WAHERB). Because each record corresponded to a voucher, uncertainty regarding identification of species could be easily dealt with. On the other hand, records from specimen databases are typically opportunistic in nature and might be expected to overlook important populations.

A number of historical records were also available. These afforded a wider context for assessing the natural occurrence of a species, but it was recognised that they might provide misleading information on the size or distribution of populations since many of the old records preceded land clearance for agriculture. This was very important in the context of threat assessment, as the occurrence of even one population in a non-vulnerable situation would increase the prospects of survival for a particular species.

Thus, the Banksia Atlas (Taylor & Hopper, 1988) was used to provide comprehensive information on the distribution of *Banksia* populations in Western Australia although it was recognised that, due to the non-vouchered nature of the data, there would be a level of uncertainty associated with plant identifications. In the case of important populations, this would require field verification.

Development of the protocol involved an expert systems approach entailing collaboration between an expert in the use of computer systems, particularly GIS, and an expert on both the pathology of *Phytophthora* and the management of its impact on native flora. This formalised, within a computer-based system, knowledge on the management of *Phytophthora* derived from many years of laboratory and field-based experience. The advantage of the strategy is that it employs that knowledge to maximum effect, with direct impact on management of disease, without resorting to the complex process of modelling behaviour of *Phytophthora* in the field.

Formulation of the protocol required a capability to easily visualise distribution maps for existing positive or negative isolations of *Phytophthora* as well as any arbitrary species of *Banksia*. Simple, uncluttered maps that display vouchered (WAHERB) and unvouchered records (Banksia Atlas; Taylor & Hopper, 1988) are needed to allow examination of both recent and historical data. Sufficient cadastral overlays should be available to facilitate knowledge of local situations.

The primary tool for visualising distribution maps was ArcView<sup>TM</sup> V3.0a (ESRI, 1997). Scripts were written in the programming language for ArcView, Avenue<sup>TM</sup>, to import data from remote sources, calculate species population numbers and rapidly display records for any given species of *Banksia*.

Banksia distribution data were imported from WAHERB and from the Banksia Atlas (Taylor & Hopper, 1988). Isolation records for *Phytophthora* spp. were sourced from the CALM Vegetation Health Service database and the Northern Sandplains Dieback Working Party (Shearer & Dillon, 1996; Stukely *et al.*, 1997).

A range of maps were visualised for each *Banksia* sp. Factors that could be used to assess the overall threat of extinction for a given species were selected from the maps and formatted as a protocol for use at both operational and resource planning levels.

# 4 RESULTS AND DISCUSSION

Assessment of the threat of extinction to a particular species requires knowledge of the factors that broadly affect the likelihood of plant mortality due to *Phytophthora*. These can be grouped into factors affecting the ability of *Phytophthora* to survive in a given

physical environment, and the ability of a plant to resist the destructive effects of pathogens either through natural immunity or through disease escape mechanisms.

#### 4.1 PHYSICAL FACTORS AFFECTING PATHOGEN ACTIVITY

The ability of *Phytophthora* to become active or reproduce is affected by a number of interacting factors in the physical environment. For example, a significant determinant in the survival and propagation of *P. cinnamomi* is the availability of adequate soil moisture. This in turn will obviously be influenced by other factors, some of which are season, rainfall and sub-surface drainage. Soil temperature is also of critical importance to production of infective zoospores by *P. cinnamomi*. A number of factors were selected to assist the development of a protocol for assessing threats of extinction using the expert systems approach. No attempt was made to document or analyse the complex interactions between factors. Rather, knowledge and experience was employed to assess how a given factor might influence the management of a particular species.

#### 4.1.1 Rainfall

Distribution records of samples tested for *P. cinnamomi* were examined. Figure 1 shows positive and negative records for the pathogen, together with annual rainfall isohyets. All positive isolations and a selection of negative samples are displayed. Selected negative samples in areas receiving less than 600mm rainfall are shown to demonstrate that absence of positive isolations in relatively dry areas is unlikely to be a result of inadequate sampling. The dense cluster of positive isolations in the 1200mm rainfall band corresponds to jarrah forest and it reflects the intensive collection effort associated with mandatory pre-logging dieback assessments.

Figure 2 shows the distributions of positive isolations for a range of *Phytophthora* spp. including *P. citricola*, *P. cryptogea*, *P. drechsleri*, *P. megasperma* and *P. nicotianae*. These distributions, together with Figure 1, confirm existing knowledge that no positive isolations of *P. cinnamomi*, or the other *Phytophthora* spp. cited above, have ever been obtained in areas receiving less than 400mm average annual rainfall.

#### 4.1.2 Climatic Zones

The climatic zones of Western Australia include the Mediterranean zone in the south-west land division (SWLD), the semi-arid and arid zones, and the sub-tropical zone of the Kimberleys in northern Australia. Although there is sufficient rainfall to support the existence of *Phytophthora* in the sub-tropical zone it has not been recorded there, possibly due to an unfavourable combination of rainfall, seasonality and temperature.

# 4.1.3 Soil Characteristics

Experience has shown that, in soils possessing similar properties to the Spearwood Dune system, there is less mortality of plants attributable to *Phytophthora* than would be expected in many other types of soil. The mechanism whereby these calcareous soils reduce plant mortality is not fully understood, but it is thought that their drainage

P. cinnamomi (a)
Sample negative (b)
Annual Rainfall
Towns

Map by Paul Gioia CALMScience Division, Department of Conservation and Land Management Northampton Dieback distribution data courtesy of Vegetation Health Service and Northern Sandplains Working Party 47 100 Kilometers Dongara **ॐ** Eneabba • Mooka Kalgoorlie Narrôgin

Figure 1. Distribution of records of isolations of a) *P. cinnamomi* and b) selected locations beyond the 600mm isohyet where no evidence of *P. cinnamomi* was found

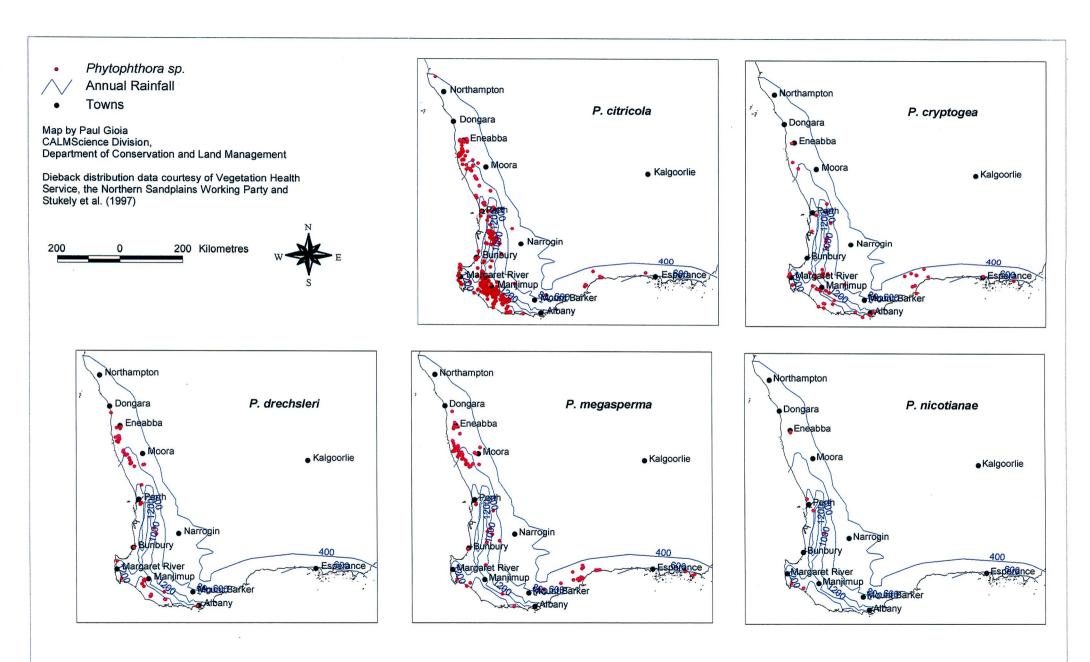


Figure 2. Distribution of records of *Phytophthora* spp. (other than *P. cinnamomi* ) in relation to rainfall zones

characteristics may play a role in preventing a build-up of soil moisture, thus inhibiting activity of the pathogen.

# 4.1.4 Topographic Position

Depending on the overall amount of precipitation, and seasonal differences in soil moisture, occupation of a high topographic position may afford some protection against *Phytophthora*. In areas receiving only 400–600mm annual rainfall, a position on ridges or hilltops might be associated with soil moisture levels that are usually too low to support the activity of *Phytophthora*. Conversely, a low topographic position in a predominantly dry area may harbour relatively high soil moisture levels, thus providing a suitable micro-environment for *Phytophthora*. Topographic position is unlikely to influence the spread of *Phytophthora* in areas receiving more than 800mm annual rainfall.

# 4.2 HOST VULNERABILITY TO PHYTOPHTHORA

The concept of vulnerability is valuable in determining the degree to which an inherently susceptible plant species may be threatened with extinction by *Phytophthora*. In the present context, vulnerability of a plant can be defined in terms of the extent to which the environment it is growing in favours survival and pathogenic activity of *Phytophthora*. Thus, a summation of the environmental factors discussed above provides an indication of vulnerability.

For example, if a susceptible plant population occupies an area receiving less than 400mm annual rainfall, it would be regarded as having extremely low vulnerability to *Phytophthora*. Conversely, a population of the same species growing within the 800mm isohyet might be regarded as extremely vulnerable unless it occurred in a protective zone such as the Spearwood Dune System. The vulnerability of a population in the 400–600mm isohyets would be influenced by its topographic position.

#### 4.3 HOST SUSCEPTIBILITY TO PHYTOPHTHORA

Also important in assessing a threat of extinction is the notion of susceptibility, i.e., the degree to which the inherent biological characteristics of a species render it sensitive to the pathogenic activity of *Phytophthora*. However, a species considered to be highly susceptible to *Phytophthora* may not be critically threatened with extinction if a number of individual populations occupy situations of low vulnerability.

There are differing views on the concept of susceptibility. If it is considered to reflect the degree to which a plant suffers physical damage, certain monocotyledons might be regarded as highly susceptible to *Phytophthora*. However, due to their ability to rapidly replace damaged roots, few symptoms are observed, and these plants are regarded as resistant, even though acting as hosts for the pathogen (Phillips & Weste, 1984). Nevertheless, very few plant species can be viewed as truly resistant to *Phytophthora* (Tippett *et al.*, 1985). In this report, the term susceptibility is used in the context of assessing threats of extinction. Species or populations that are unlikely to die as a result of infection with *Phytophthora* are regarded as non-susceptible.

#### 4.4 DISEASE ESCAPE

Although a species may be deemed highly susceptible to *Phytophthora*, its regenerative capability might afford a mechanism for survival. After an infection front has passed through a plant community, the number of individuals of a highly susceptible species is often drastically reduced. As a consequence, the number of hosts available to the pathogen is correspondingly diminished and its inoculum reservoir decreases accordingly. If the time required for surviving individuals to flower is sufficiently short, seed setting may occur before the pathogen inoculum base has reattained a critical level. Therefore, when applying the protocol for assessing threat of extinction, species within a worst case scenario should also be assessed for possible survival through disease escape.

#### 4.5 PROTOCOL FRAMEWORK

Based on the vulnerability of individual populations of species, and the notions of susceptibility and disease escape, an initial framework for assessing threats of extinction can be specified. This should not be seen as definitive for any specific situation, but rather as a model on which to base an operational framework. It is also notable that the framework is predicated on a worst case scenario – that the spread of *Phytophthora* is inevitable throughout all niches in which it can survive. This is an unfortunate, but entirely possible scenario that should be recognised and incorporated in management planning.

The various factors described above can be framed as a series of questions to be asked of a given species. Each question acts as a filter that will influence the final determination of threat of extinction. These questions are summarised below, with a view to rating the threat of extinction from *Phytophthora* for a given species:

1. Is the species considered highly susceptible to Phytophthora?

Yes: Go to 2

No: No threat of extinction

2. Does the species have a mechanism such as disease escape to ensure survivors?

Yes: No threat of extinction

No: Go to 3

3. Are any or all populations of the species located in a rainfall zone receiving less than 400mm annual precipitation?

Yes: No threat of extinction

No: Go to 4

4. Are all known populations of the species restricted to a subtropical zone?

Yes: No threat of extinction

No: Go to 5

5. Do any populations occur on soils similar to the Spearwood Dune system?

Yes: Verify the existence of populations in the field and their actual occurrence within the protective soil zone. If populations are extant, then species may not be threatened with extinction so long as their component populations are

managed defensively to prevent inadvertent spread of the pathogen. No: Go to 6

6. Do any populations occur within the 400–600mm annual rainfall zone? Yes: Assess the topographic position of each of these populations by reference to existing records. If necessary, verify the presence of populations in the field and assess their vulnerability. The species may not be threatened with extinction providing that some populations do not occupy vulnerable situations, and that these are managed defensively to prevent inadvertent spread of the pathogen.

**No**: Go to 7

7. Do all populations occur in areas receiving more than 600mm annual rainfall? Yes: If there are no extant populations in any of the protective situations described above, then this species is threatened with extinction because of the inevitable spread of *Phytophthora* throughout localities receiving rainfall in excess of 600mm. Extant populations should be managed using intensive methods such as fencing and, if necessary, phosphonate application.

#### 4.6 CASE STUDIES WITH BANKSIA SPECIES

The distribution of all available *Banksia* records for south Western Australia is shown in Figure 3, with rare or priority species differentiated from other taxa by a contrasting symbol. The distribution is overlain with mean annual rainfall isohyets and with isolation records for *P. cinnamomi*. The genus *Banksia* is widespread throughout the SWLD, with most records occurring in areas receiving more than 400mm annual rainfall. There are a number of clusters of rare or priority taxa. Of particular note are those in the Stirling Range National Park and on the south coast, directly east of Albany, where relatively heavy infestations of *P. cinnamomi* are present.

Threats of extinction to species of *Banksia* were assessed for as many situations as possible, using the draft framework outlined in Section 4.5. A sufficient number of taxa were examined to cover the broad spectrum of situations that populations of any given species might experience.

The distributions of four selected species are displayed in separate maps (Figures 4, 5, 6 and 7) each of which includes records from both WAHERB and the Banksia Atlas (Taylor & Hopper, 1988). The maps all comprise annual rainfall isohyets and a crude representation of the extent of the Spearwood Dune system. The numbers of records from each source of *Banksia* data is displayed for four rainfall zones. The *Banksia* spp. selected for examination (see below) were all considered to be susceptible to *Phytophthora*.

## 4.6.1 Banksia audax

B. audax is restricted to a region extending from the Goldfields, west of Kalgoorlie, to the Great Southern wheatbelt east of Narrogin (Figure 4). All recorded populations lie within a zone receiving less than 400mm annual rainfall. Therefore, this species is under no threat of extinction from *Phytophthora*.

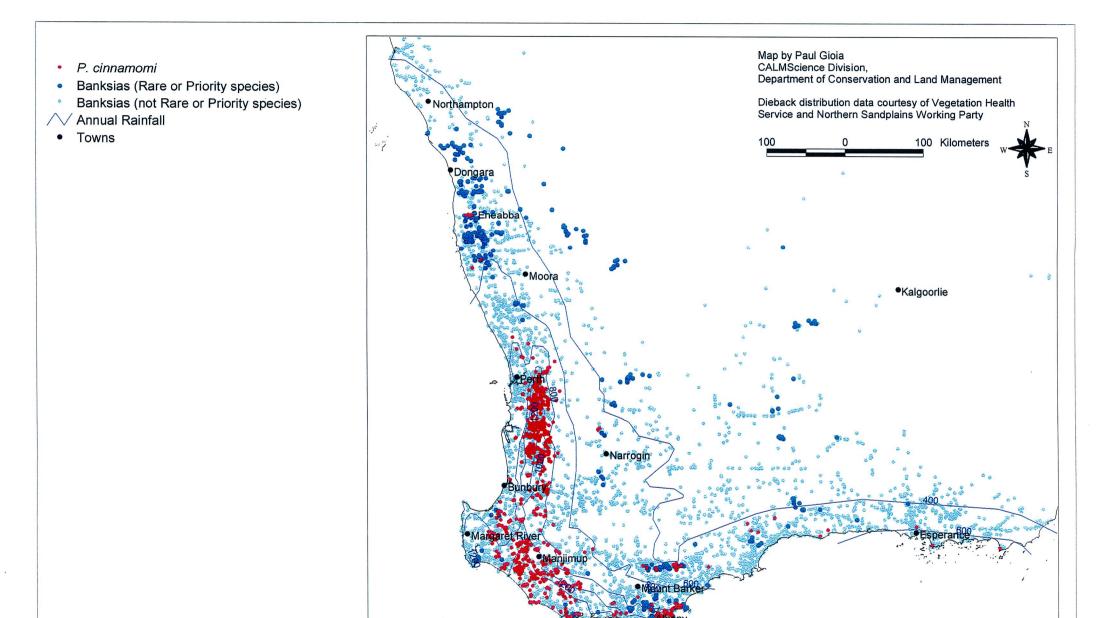


Figure 3. Distribution of the genus *Banksia* in relation to survey for the presence of *P. cinnamomi* 

Banksia Atlas records

Spearwood Dune System

Annual Rainfall

| Rainfall  | No. of Records |       |
|-----------|----------------|-------|
| (mm)      | WAHerb         | Atlas |
| < 400     | 14             | 33    |
| 400 - 600 | 0              | 0     |
| 600 - 800 | 0              | 0     |
| 800+      | 0              | 0     |

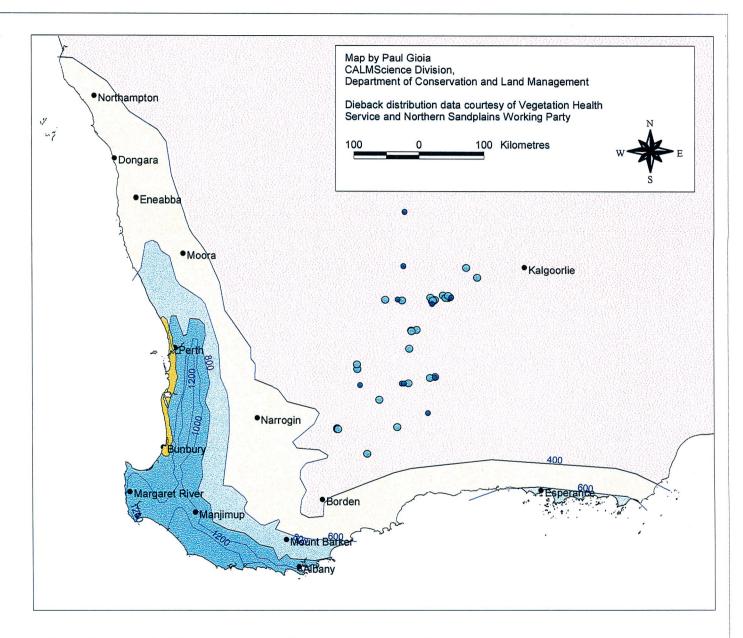


Figure 4. Distribution of records of Banksia audax in relation to rainfall zones and the Spearwood dune system

Banksia Atlas records

Spearwood Dune System

Annual Rainfall

| Rainfall  | No. of Records |       |
|-----------|----------------|-------|
| (mm)      | WAHerb         | Atlas |
| < 400     | 2              | 0     |
| 400 - 600 | 3              | 69    |
| 600 - 800 | 2              | 12    |
| 800+      | 0              | 0     |

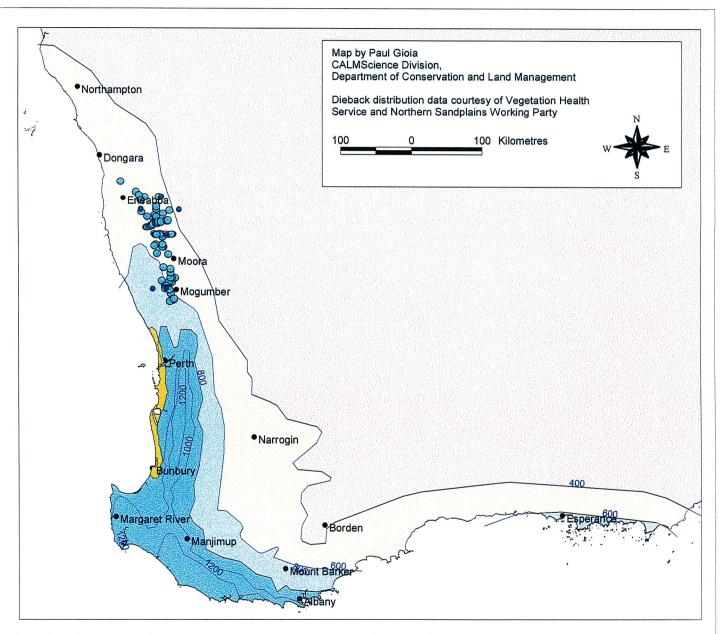


Figure 5. Distribution of records of Banksia burdettii in relation to rainfall zones and the Spearwood dune system

Banksia Atlas records

Spearwood Dune System

Annual Rainfall

| Rainfall  | No. of Records |       |
|-----------|----------------|-------|
| (mm)      | WAHerb         | Atlas |
| < 400     | 0              | 0     |
| 400 - 600 | 18             | 97    |
| 600 - 800 | 5              | 27    |
| 800+      | 18             | 43    |

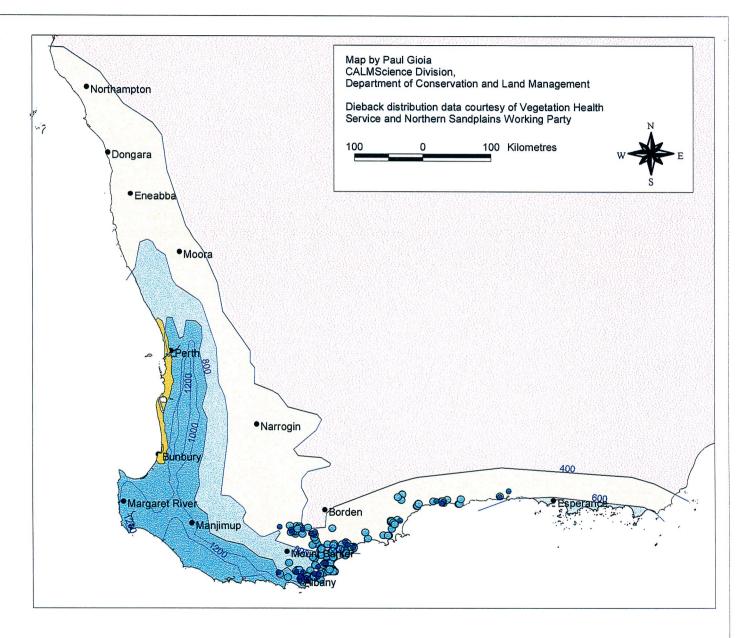


Figure 6. Distribution of records of Banksia coccinea in relation to rainfall zones and the Spearwood dune system

Banksia Atlas recordsSpearwood Dune System

Annual Rainfall

| Rainfall  | No. of Records |       |
|-----------|----------------|-------|
| (mm)      | WAHerb         | Atlas |
| < 400     | 0              | 0     |
| 400 - 600 | 10             | 205   |
| 600 - 800 | 16             | 392   |
| 800+      | 89             | 1287  |

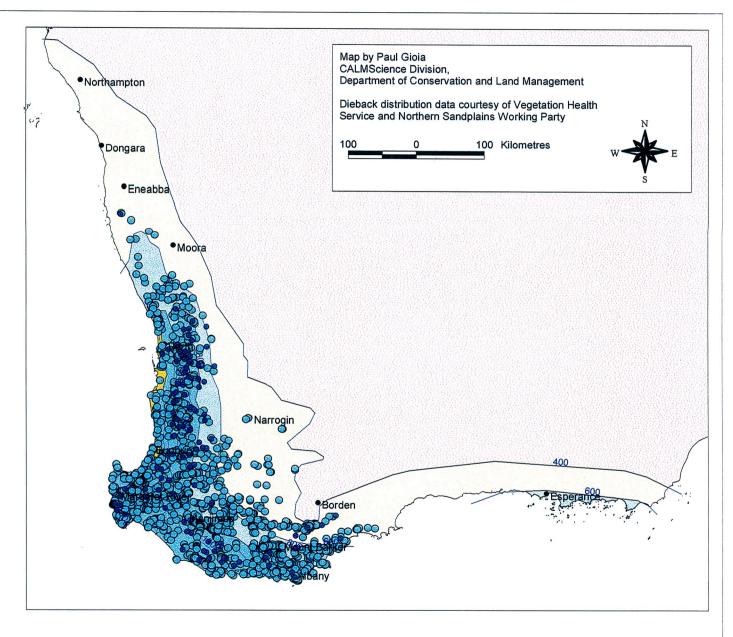


Figure 7. Distribution of records of Banksia grandis in relation to rainfall zones and the Spearwood dune system

#### 4.6.2 Banksia burdettii

B. burdettii is restricted to an area between Eneabba and Mogumber. About a third of the populations listed in the Banksia Atlas were recorded in conservation reserves, whereas most other populations were found on road verges bordering agricultural land. Atlas records are confined to white or yellow sandplain as a component of shrubland or, less commonly, woodland (Taylor & Hopper, 1988).

Figure 5 shows the available records for *B. burdettii*, most of which relate to areas receiving between 400mm and 600mm annual rainfall. Application of the protocol (Section 4.5) leads to a positive response for Question 6 which states that populations in the 400-600mm rainfall zone are vulnerable unless they are located in topographically elevated positions on the landscape. Because *B. burdettii* occurs mainly in low lying areas, the threat of extinction posed to this species by *Phytophthora* appears to be moderately high, at least in a worst case scenario.

Although there are just seven herbarium records for *B. burdettii*, as opposed to eightyone in the Banksia Atlas (Taylor & Hopper, 1988), only moderate range extension is associated with the latter. Two herbarium records from 1939 relate to populations in a relatively dry zone between Marchagee and Coorow. In the unlikely event that these two populations are extant, the threat of extinction would be significantly diminished.

Management options for protection of *B. burdettii* would require that all available records be examined to determine the topographic position of individual populations. Any records of up-slope populations would need to be confirmed in the field before possible control measures were investigated.

#### 4.6.3 Banksia coccinea

Figure 6 shows the recorded occurrences of *B. coccinea*. This species has a near-coastal distribution on the southern sandplain of the SWLD with inland populations mostly located in the Stirling Ranges or the north-western corner of Fitzgerald River National Park. *B. coccinea*, which is highly susceptible to *P. cinnamomi*, prefers flat or gently undulating landforms, with one exception on Ellen Peak in the Stirling Ranges (Taylor & Hopper, 1988).

With reference to the protocol, all records of *B. coccinea* are for areas where annual rainfall exceeds 400mm, with almost half of those receiving more than 800mm. Most records for the 400-600mm zone relate to low-lying areas. *B. coccinea* should therefore be viewed as under an extremely high threat of extinction.

#### 4.6.4 Banksia grandis

B. grandis has a widespread distribution throughout the coastal plain and Darling plateau, extending from Mt. Lesueur south to Augusta and east to Bremer Bay (Figure 7). Records from the Banksia Atlas indicate that the range of B. grandis extends as far inland as Badgebup and Dongolocking Nature Reserve, and that the species tends to occur on flat or gently sloping landforms (Taylor and Hopper, 1988).

All records of *B. grandis* are derived from zones receiving more than 400mm annual rainfall, with most relating to areas where the yearly average exceeds 800mm. Because the vast majority of recorded occurrences in the lower rainfall zone are also from low-lying sites, most populations of *B. grandis* are highly vulnerable to *Phytophthora*. One possible protective zone is the Spearwood Dune system for which a number of records occur, primarily in the Banksia Atlas (Taylor & Hopper, 1988).

Contrary to popular belief, the threat of extinction to *B. grandis* is much greater than might be expected, despite the widespread distribution of the species. The focus on geographically restricted taxa may sometimes tend to divert attention from the plight of currently widespread species that may ultimately become endangered.

# 5 OUTCOMES

- Methodology was successfully developed for the formulation of a protocol to evaluate threats of extinction posed by *Phytophthora* to taxa of native plants. The protocol was designed to assist management decisions in priority setting for application of limited resources essential to the protection of native biota under existing or immediate threat of extinction due to the activity of the pathogen.
- The protocol was based on the combination of expert knowledge obtained from a recognised authority on the pathology and management of *Phytophthora*, together with input from a specialist in the use of computer systems, particularly GIS. The advantage of an expert systems approach is that it obviates the requirement for modelling the complex behaviour of *Phytophthora* in natural environments, a task that is likely to be extremely difficult.
- Another advantage of this approach, is that application of the simple protocol
  described here does not require rigorous training or extensive prior knowledge.
  Thus, it can readily provide key assistance to land managers in the course of
  decision making for prioritisation of resources in plant protection.
- The study of *B. grandis* has raised the possibility that some widespread species of susceptible native plants might be under a significant threat of extinction in a worst case scenario in which *Phytophthora* eventually occupies all niches available to it, and where the distributions of the host and pathogen then coincide.

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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

#### **DECEMBER 1998**

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