PROJECT 6

CONTROL AND MANAGEMENT OF *CRYPTODIAPORTHE MELANOCRASPEDA* CANKER THREATENING *BANKSIA COCCINEA*

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1 INTRODUCTION

Banksia coccinea R. Br. occurs in shrubland communities on the southern sandplain of Western Australia, mainly within the region bounded by Albany in the west, the Stirling Range in the north, and the Young River in the east. This region has been extensively cleared for agriculture, but substantial areas of native vegetation remain in reserves that are managed primarily for nature conservation. These reserves range in size from large national parks such as the Fitzgerald River and Stirling Range National Parks to small corridors along roadsides. Bushland remnants on private property also make an important contribution to conservation, but there is wide variation in the degree of protection or management provided to such remnants. Although natural stands of *B. coccinea* have in the past been subject to harvesting by wildflower pickers (Robinson 1991), this practice has been banned on Crown land since 1991.

Serious decline of *B. coccinea* was first reported in 1989 (Shearer and Fairman 1991), and subsequent work has implicated the ascomycete *Cryptodiaporthe melanocraspeda* as the causal agent of a destructive canker disease affecting the species (Bathgate and Shearer 1995, Bathgate *et al.* 1996). The disease is notable for causing rapid decline under some circumstances, and in an extreme case near Cheyne Beach, Shearer *et al.* (1995) reported that plant mortality increased from 40% to 98% during a period of only 2.7 years. However, disease severity varies widely and relatively healthy stands remain throughout the range of *B. coccinea*. There is evidence that stress associated with very high temperatures and strong winds may have triggered a major expansion of canker disease in 1991 (Robinson 1991, Wills and Keighery 1994).

Previous research has investigated various aspects of the disease and its impact on *B. coccinea* including seed bank dynamics of that species, sources of fungal inoculum and conditions favouring spore release, the infection process, factors influencing disease severity, and management strategies to minimise disease (Bathgate and Shearer 1995, Shearer *et al.* 1995).

The shrubland plant communities in which *B. coccinea* occurs are prone to periodic fire and the potential role of fire in management of canker-affected stands has been recognised. Bathgate and Shearer (1995) demonstrated a pattern of increasing disease severity with increasing stand age, and consistently recorded cankers in stands older than 14 years. The importance of unburned remnants of old stands as foci for infection of adjacent, younger regeneration was also confirmed, suggesting that fire regimes which create mosaics of small patches of unburned vegetation could favour disease development.

In 1995 the emphasis of research was shifted from the epidemiology of the disease to the ecology of the host. The rationale behind this, was that an understanding of the autecology of *B. coccinea* would be necessary for development of management strategies designed to maintain viable populations of *B. coccinea* in the presence of disease. In particular, differences in longevity and regenerative capacity between severely diseased and relatively healthy stands could be important in determining appropriate fire regimes. Witkowski *et al.* (1991) studied the seed bank dynamics of two *B. coccinea* populations at Hopetoun and concluded that the species had an earlier peak of seed production, a shorter life span, and a greater capability for interfire establishment than the co-occurring *B. baxteri* and *B. speciosa*. The older of the two populations (21 years) was in an advanced state of decline with over half the plants dead and the remainder senescent with dieback of branches. Although canker-causing fungi were collected from moribund shoots of *B.coccinea*, the authors did not consider that the observed decline was entirely attributable to disease. Witkowski *et al.* (1991) hypothesised that fire intervals which exceeded the life span of *B. coccinea* would lead to the demise of the species, unless favourable environmental conditions led to substantial recruitment during the interfire period. Based on observations of longevity for the Hopetoun population, fire intervals greater than 20 years were suggested as being likely to disfavour the persistence of *B. coccinea*.

2 OBJECTIVES

The work described in this report was undertaken to extend the knowledge of the autecology of *B. coccinea,* and in particular the interactions between fire, plant longevity, and regeneration. A secondary aim of the project was to establish a series of permanent sampling sites in *B. coccinea* stands which could provide the basis for longer term monitoring of stand health and condition.

3 METHODS

3.1 HEALTH AND CONDITION OF *B. COCCINEA* IN RELATION TO STAND AGE.

Previous work by Bathgate and Shearer (1995) indicated a direct relationship between increasing stand age and disease severity and they recorded cankers in all surveyed stands of *B. coccinea,* 14 years of age or older. This trend was identified from analysis of a database comprising 52 sites spanning the range of the species as far east as the Pallinup River. These sites fell into two broad groups: a coastal group which included sites from just north of the Hassell Highway southwards to the coast, and an inland group located in the Stirling Range National Park. Eighteen of the coastal sites supported stands of at least 14 years' age, but stands on only seven of the inland sites were 14 years or older. In selecting additional locations for assessment of stand structure and condition in the present study, priority was therefore given to sites bearing stands older than 14 years in the Stirling Range National Park and surrounding areas. Several sites were also established around Hopetoun at the eastern limit of the range of *B. coccinea,* up to 150 km further east than any of the locations assessed by Bathgate and Shearer (1995).

Potential stands were characterised using a variety of information derived from fire history maps maintained by the Department of Conservation and Land Management, aerial photographs, local knowledge of *B. coccinea* occurrence, or field reconnaissance. In most cases the age of the vegetation could be confirmed from fire history records, or through examination of sequential air photographs which also made it possible to determine the minimum length of time since fire had occurred. Sometimes the minimum time since fire, was estimated from the height and structure of vegetation.

At each site, a transect was established to survey the structure and condition of the *B. coccinea* stand. The starting point for each transect was marked with a steel fence dropper, the location of which was fixed with a Global Positioning System to permit its' re-location in the event of damage or loss. The transect was defined by the distance and magnetic bearing to a series of individual *B. coccinea* plants that were spaced at a distance of more than 2 m apart, and in most cases represented the next closest individual or clump of plants. These individuals were numbered with aluminium tags and used as the centre point for a circular quadrat of 2 m radius in which the height to growing tip was recorded. Severity of limb dieback was assessed using the classification scheme employed by Bathgate and Shearer (1995) which rated the percentage of dead limb area in classes of 0%, <10%, 10-25%, 25-50% and >50%. The age of *B. coccinea* was estimated using the node counting technique of Lamont (1985). All transects were established between March and December 1996.

3.2 SEEDLING REGENERATION FOLLOWING FIRE IN AN OLD STAND.

The opportunity to examine the extent of seedling regeneration of *B. coccinea* following fire in an old stand (>45 years since previous fire) arose when an area of mallee heath at the southern end of Talyuberlup Track in the Stirling Range National Park was burned in April 1996. This stand included a number of large, widely-spaced *B. coccinea* individuals which were in good condition prior to the fire, with little or no evidence of limb dieback despite their age. The wildfire was of high intensity and consumed the foliage on all plants up to at least 4 m above ground, together with the lower shrub layer and all leaf litter on the ground. All plants were killed by the fire which occurred before a formal assessment of limb dieback severity could be undertaken. A transect was established in the manner previously described, and the height of each plant was recorded. The number of *B. coccinea* seedlings within 2 m of each fire-killed mature plant were estimated eight months after the fire.

3.3 GROWTH AND FLOWERING IN *B. COCCINEA*.

Growth in height and flowering were examined for two populations of *B. coccinea* seedlings near Two Mile Lake at the south-eastern corner of the Stirling Range National Park. These populations, which occurred on closely similar sites either side of a fire access track, had regenerated following fires in autumn 1989 or spring 1990. Twenty plants in each population were assessed during late August/early September in 1994, 1995 and 1996, and again in December 1996.

4 RESULTS

4.1 HEALTH AND CONDITION OF *B. COCCINEA* IN RELATION TO STAND AGE.

4.1.1 Transects

Eleven transects were established to supplement the earlier work by Bathgate and Shearer (1995). The total length of transect and number of *B. coccinea* sampled were 1143 m and 412 plants respectively. Seven transects were located in or around the Stirling Range National Park, two were at the eastern limit of the species distribution near Hopetoun, and two were in coastal sites at Wellstead and Waychinicup (Figure 1). Location details for the eleven transects are provided in Appendix A. An additional stand of unburned (>20 years) *B. coccinea* was identified (Site 8, Appendix A) but a transect was not established there because the site showed evidence of considerable disturbance and was threatened by dieback infection which would have complicated long-term monitoring of canker disease.

Stands in which transects were established had not experienced fire for at least five years and in most cases there was no evidence of fire in the decade preceding this work. Information on stand age and density, numbers of *B. coccinea* examined and transect data is given in Table 1. Node counts tended to underestimate the age of plants, particularly those older than 20 years. This was probably due to nodes becoming obscured by stem thickening with increasing plant age.

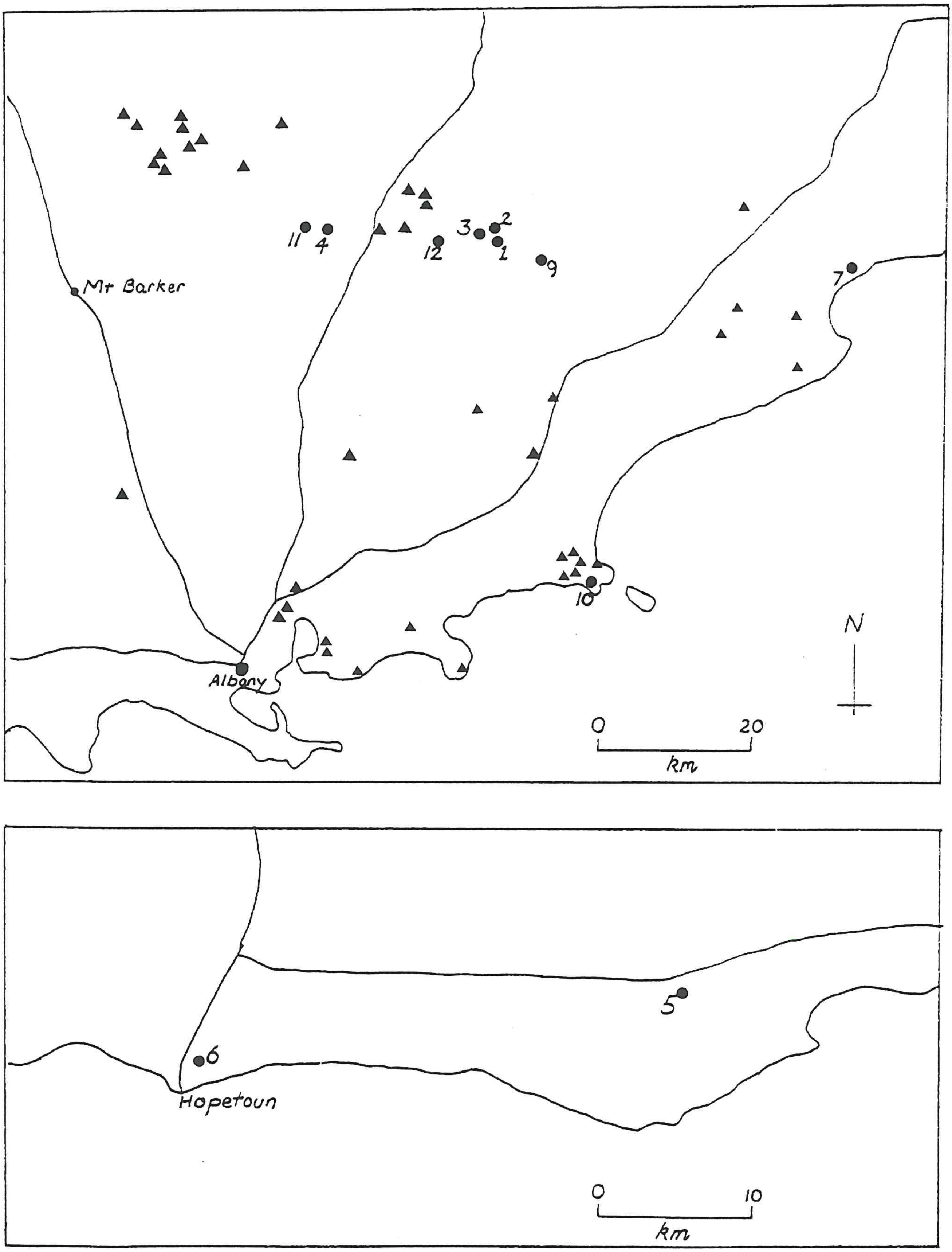


Figure 1. Map showing the distribution of sites surveyed for severity of limb dieback by Bathgate and Shearer (1995) (▲), and in the present study (●).

Table 1. Stand age and sampling details for 11 transects established to assess the structure and condition of *B. coccinea* populations. Maximum stand density for each transect represents the greatest number of plants recorded within a circular quadrat of 2 m radius. Sites in the Stirling Range National Park are shown as SRNP.

SITE	LOCATION	STAND AGE (years)	NO. OF B.coccinea ASSESSED	LENGTH OF TRANSECT (m)	MAXIMUM STAND DENSITY (plants/ha)
1	SRNP	27^{A}	8	16	1592
2	SRNP	27^{A}	69	118	19900
3	SRNP	27^{A}	41	103	6368
4	SRNP	$>45^{B}$	5	14	3184
5	HOPETOUN	$>20^{C}$	33	114	3980
6	HOPETOUN	$>20^{C}$	31	288	2388
7	WELLSTEAD	$6\text{-}9^{C}$	51	43	15124
9	CHILLINUP RD	$>25^{C}$	34	33	10348
10	WAYCHINICUP	$10\text{-}14^{C}$	78	2	62088
11	SRNP	$>45^{B}$	15	359	1592
12	SRNP	10^{A}	47	53	10348

Footnote:

Stand age information was rated according to the following reliability codes

A - determined from known year of last fire

B - determined from examination of sequential air photographs

C - determined on the basis of observed vegetation structure

4.1.2 Stirling Range National Park

Sites 1, 2 and 3 were located in mallee heath in the south-eastern corner of the Stirling Range National Park that was last affected by wildfire in 1969. Although located in the same region the three stands were separated from one another by areas of mallee which did not contain *B. coccinea*. These stands were similar in structure, with the majority of plants being 2-3 m tall (Figure 2). Site 1 differed from the other two in having three seedlings that had obviously been recruited within the past one or two growing seasons. Most plants at sites 1 and 3 were either healthy or affected to only a slight degree by limb dieback (<10%) and the level of mortality was very low (2% or less). Limb dieback and mortality was more common at Site 2, particularly for trees in the 1-2 m height class. In contrast, none of the dominant plants (3-4 m tall) were seriously affected by limb dieback. Maximum stand densities at Site 2 were very high (Table 1) and the relatively frequent occurrence of mortalities among the smaller plants was consistent with strong intra-specific competition for resources and space.

Site 9 was located on a similar landform to Sites 1, 2 and 3 but about 10 km to the south-east. The stand at Site 9, which had a similar structure to those on the first three sites, showed very little evidence of limb dieback associated with canker disease.

Site 12 was established in an area of open *Banksia* heath last burned in October 1986. This site was selected to increase the representation of younger stands in the data set for the Stirling Range area so that trends in stand health with increasing age could be more thoroughly examined. All plants at this site were rated healthy with no evidence of limb dieback. The vegetation at Site 12 was notably rich in *Banksia* spp. with *B. baxteri*, *B. attenuata*, *B. repens*, *B. nutans* and *B. gardneri var. gardneri* observed in addition to *B. coccinea*.

The oldest stands of *B. coccinea* located during the survey were at Sites 4 and 11 in mallee heath on the southern edge of the Stirling Range National Park (Figure 1). Prior to wildfire in April 1996 this area had not been burned for more than 45 years. Site 4 comprised an isolated patch of five *B. coccinea* trees, three of which were 4.2 - 4.5 m tall, while the others were 2-3 m tall and appeared to be suppressed plants of the same age. The extent of limb dieback was only minor (<10 %) on the dominant plants, and moderate (10-25%) on the smaller ones. Site 11 was not assessed for canker disease prior to the wildfire, although a preliminary inspection had suggested that most plants were healthy. Dominant plants were 4-4.5 m tall, and more than two thirds of the population exceeded 3 m in height. The smallest plant appeared to be a recent recruit rather than a suppressed individual from the same cohort as the dominants. The density of plants at Site 11 was the lowest recorded at any site, both in terms of maximum density and number of plants encountered (equivalent to 4 plants/100 m of transect).

4.1.3 Hopetoun

The two sites (5 and 6) in the Hopetoun area were at least 20 years old and of similar structure, with the majority of plants being 2-3 m tall, while some exceeded 3 m in height (Figure 2). At Site 5 most plants exhibited little or no limb dieback (0-10%), while a small number were either severely affected or dead. The proportion of plants with moderate (10-50%) limb dieback was greater at Site 6 although no deaths were recorded there.

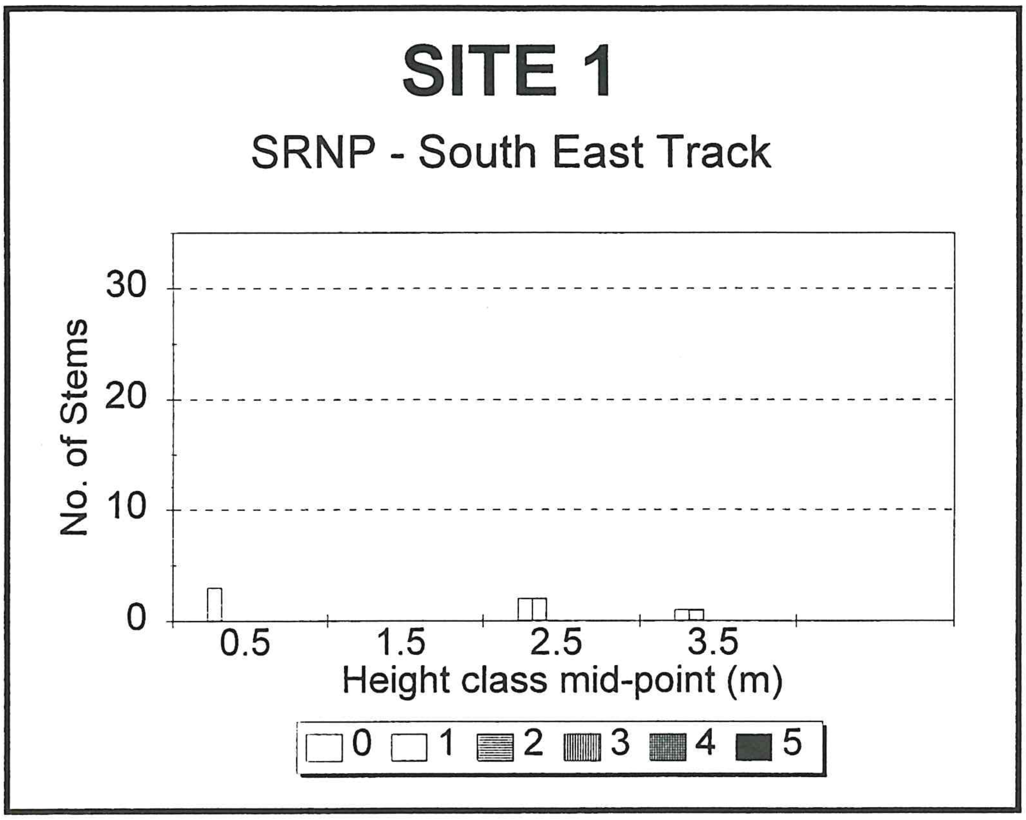
4.1.4 Wellstead and Waychinicup

Site 7 at Wellstead supported a relatively young stand which was estimated to be 6-9 years old on the bases of plant height and the number of flowering nodes on *B. coccinea.* The tallest plants in this population were about 1.8 m, and the majority showed no evidence of limb dieback (Figure 2). However, about 10% of the plants were dead. Samples of stem tissue collected from recently dead plants were found to be infected with *Cryptodiaporthe* (pers. comm., C. Crane, CALM, Como).

The population at Waychinicup (Site 10) was aged between 10 and 14 years and was extremely dense with 78 plants recorded within a quadrat of 2 m radius (Table 1). This population was subject to severe infection by *C. melanocraspeda* and about 55% of plants were dead (Figure 2). Of the surviving plants, more than 50% showed moderate to severe degrees of limb dieback.

4.1.5 Re-examination of Trends in Disease Severity with Increasing Stand Age.

Information relating to the stands of *B. coccinea* inspected in this work were combined with earlier data from Bathgate and Shearer (1995) to further examine the relationship between



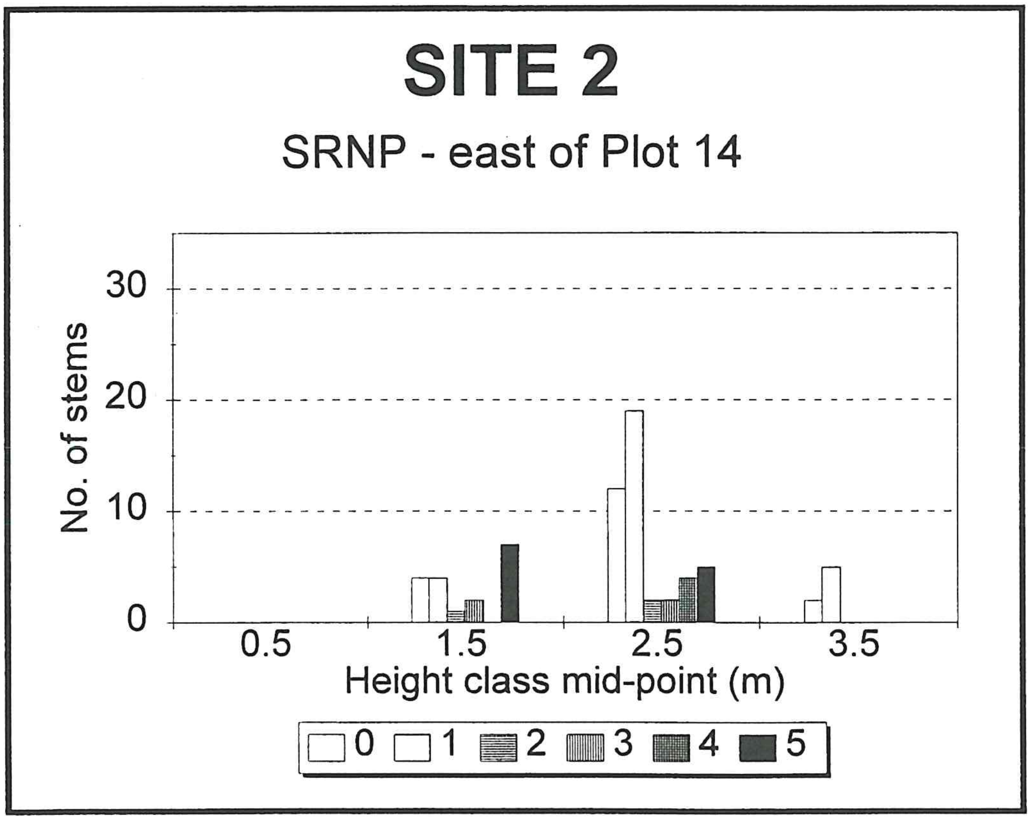
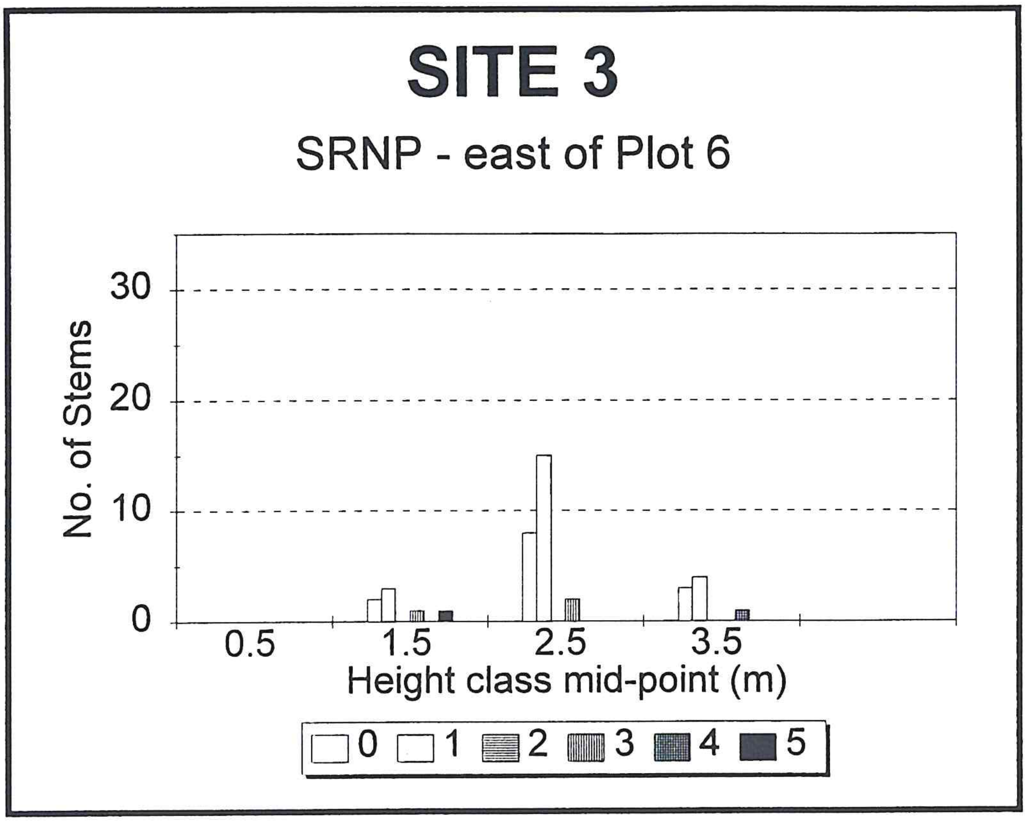
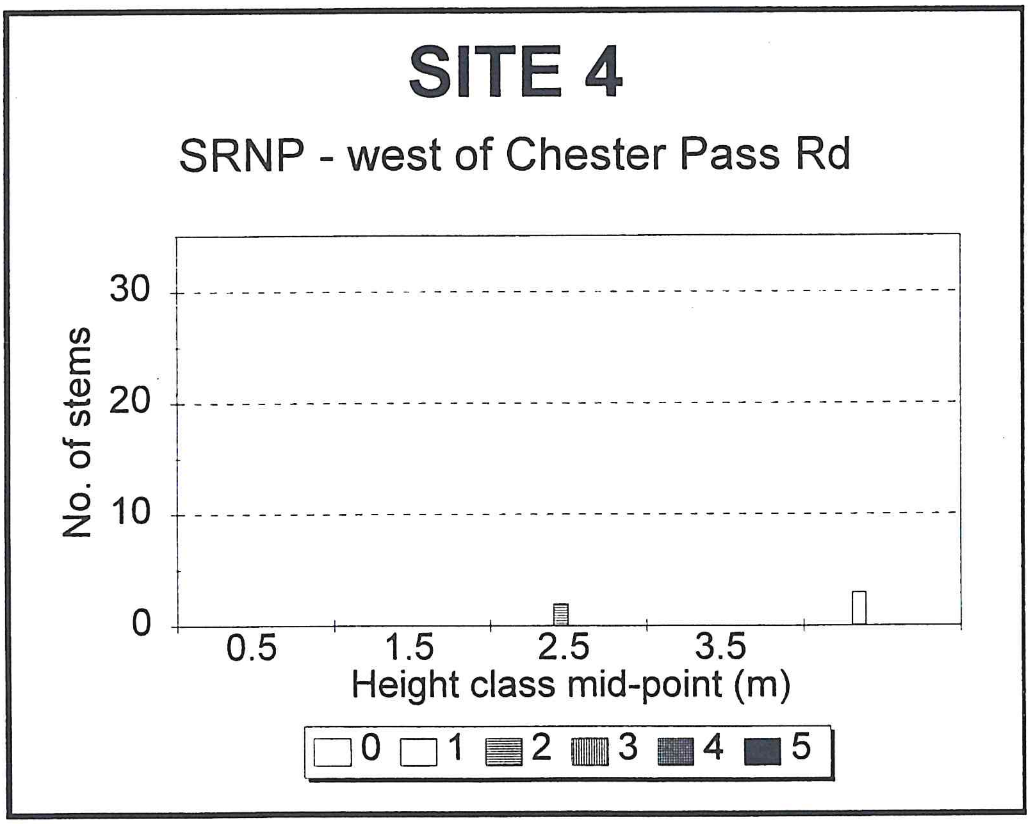


Figure 2. Histograms showing the number of stems sampled at eleven sites in the present study according to plant height and limb dieback severity class. Limb dieback was described in severity classes of (0) no limb dieback, (1) <10%, (2) 10-25%, (3) 25-50%, (4) >50% of dead limb area per plant. Severity class (5) represents dead plants. Site 11 was not assessed for limb dieback because it was burned by an unplanned fire before assessment could be undertaken.





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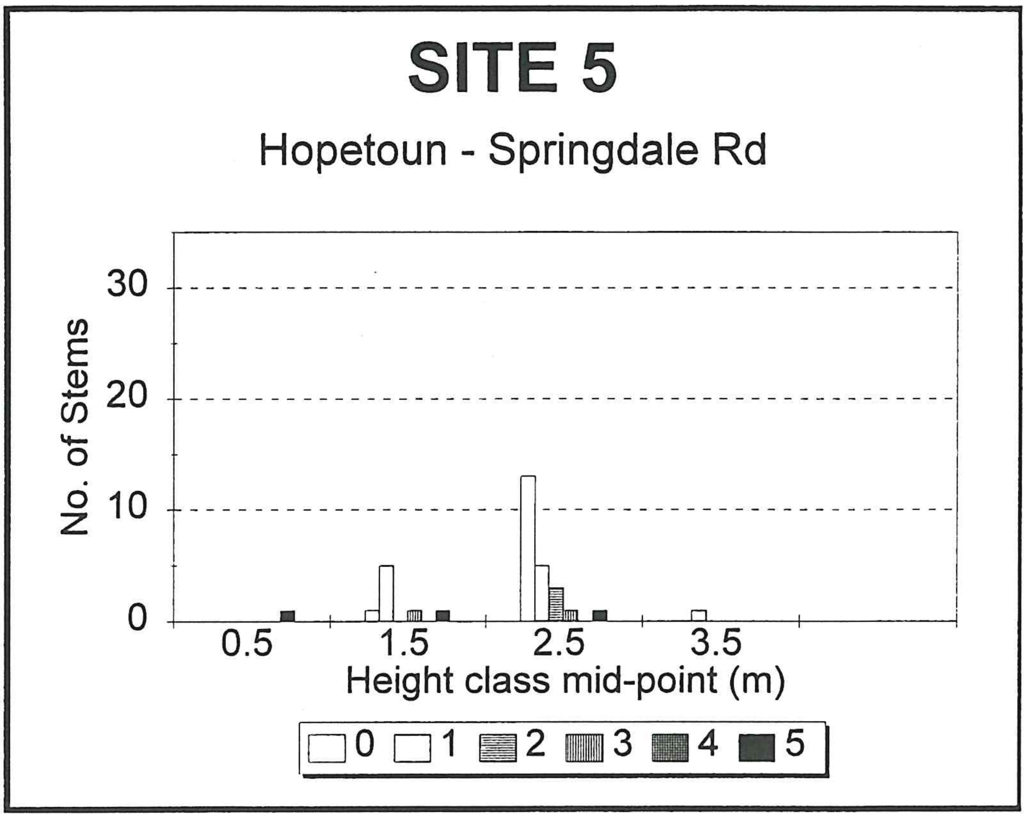

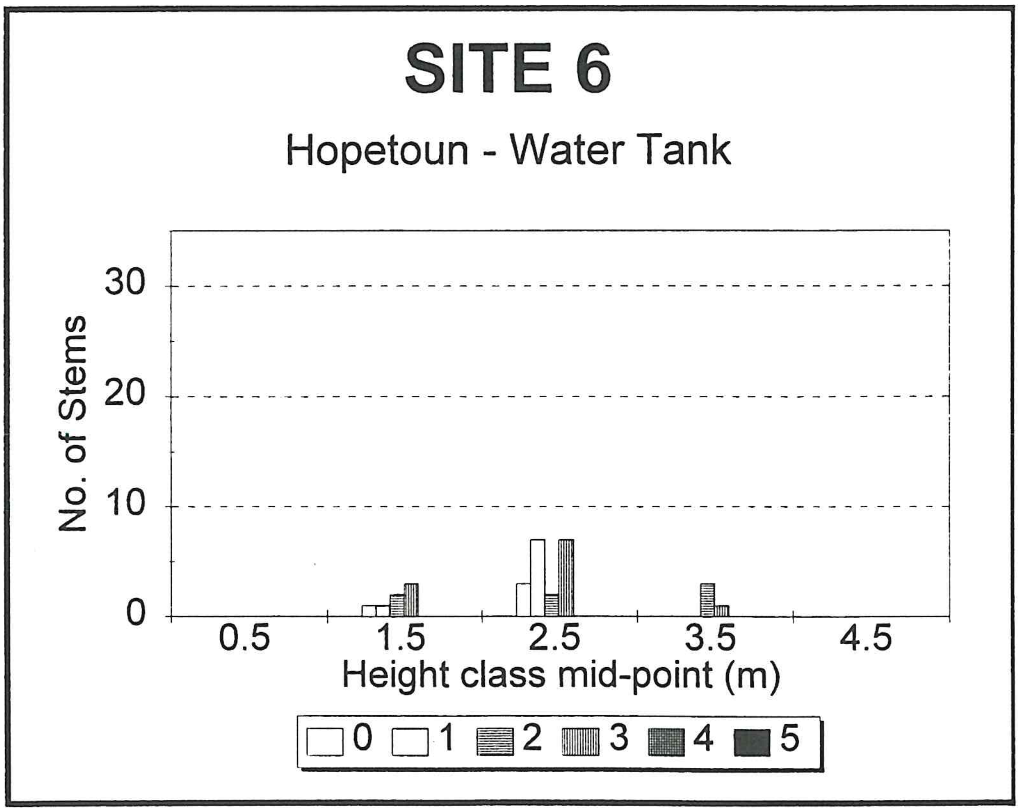

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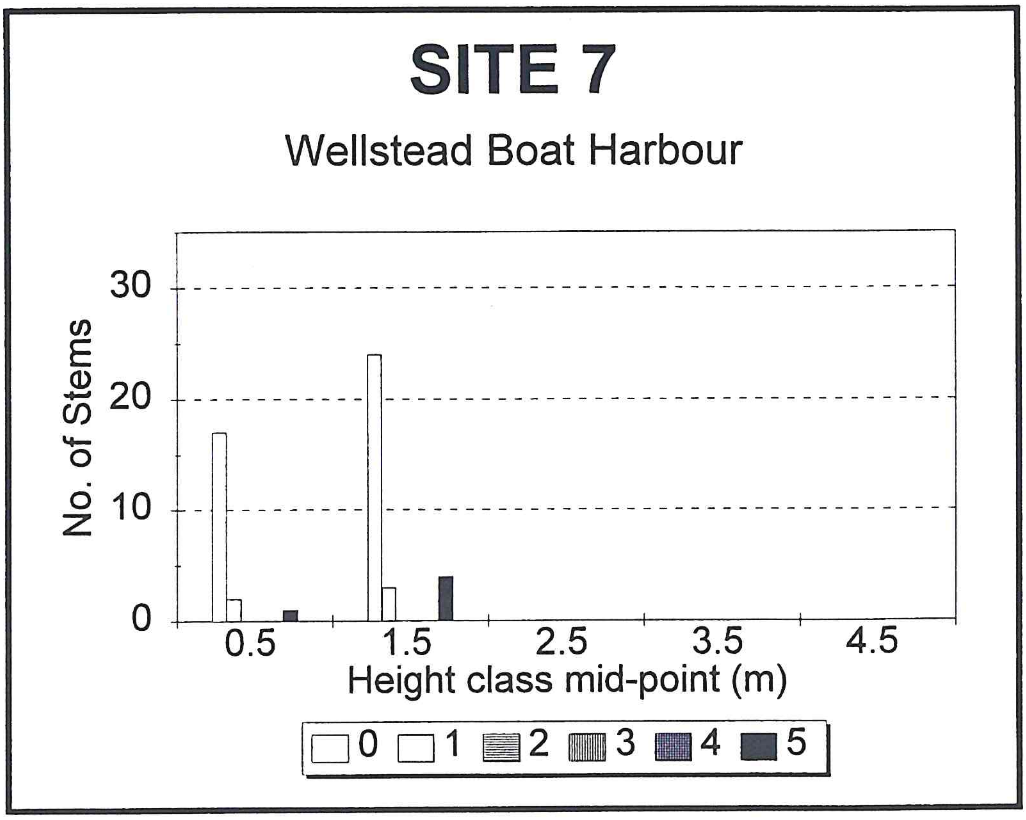

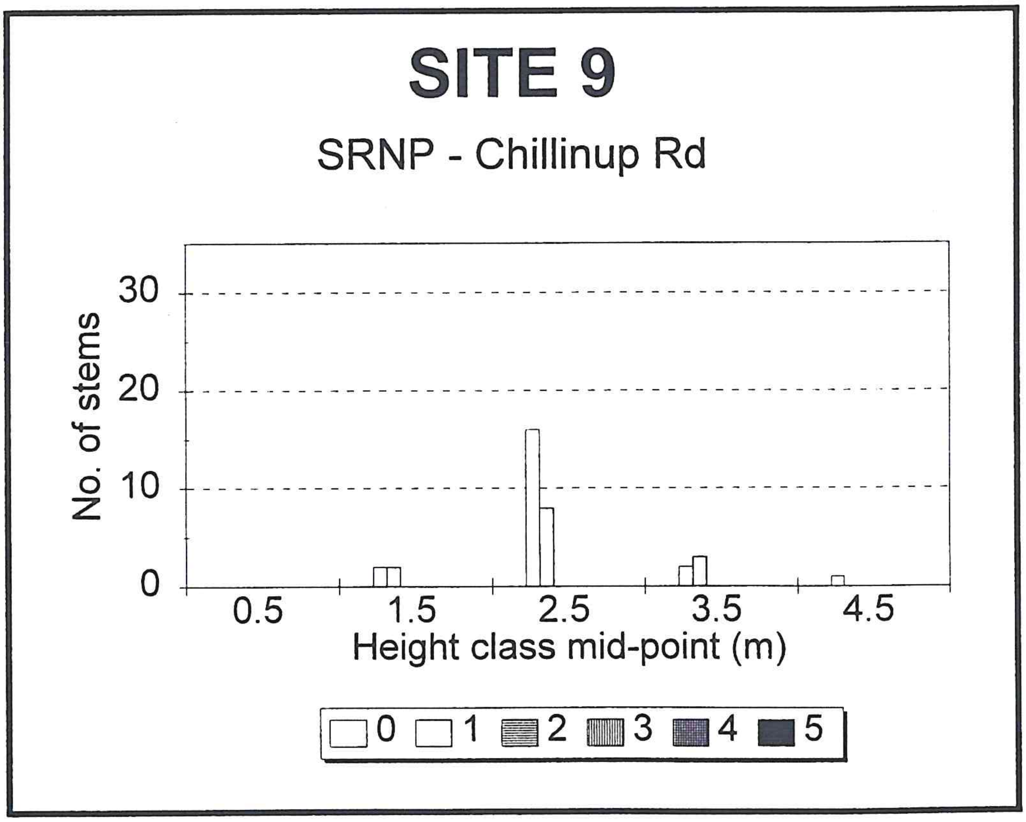

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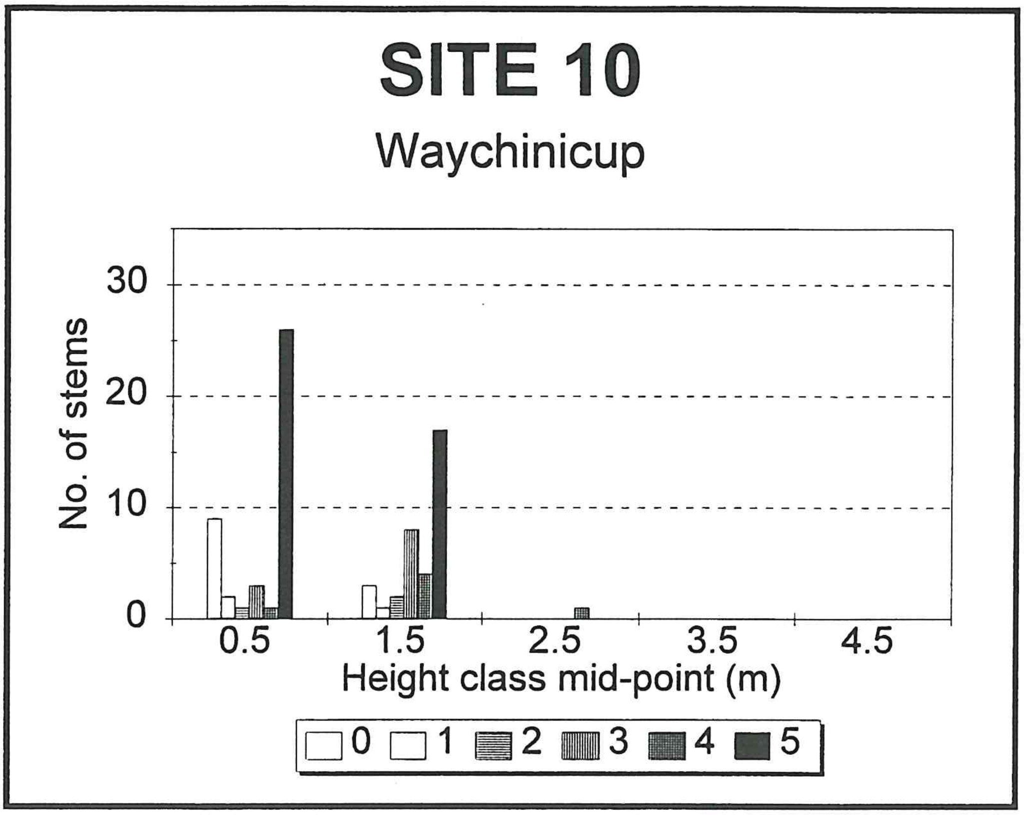

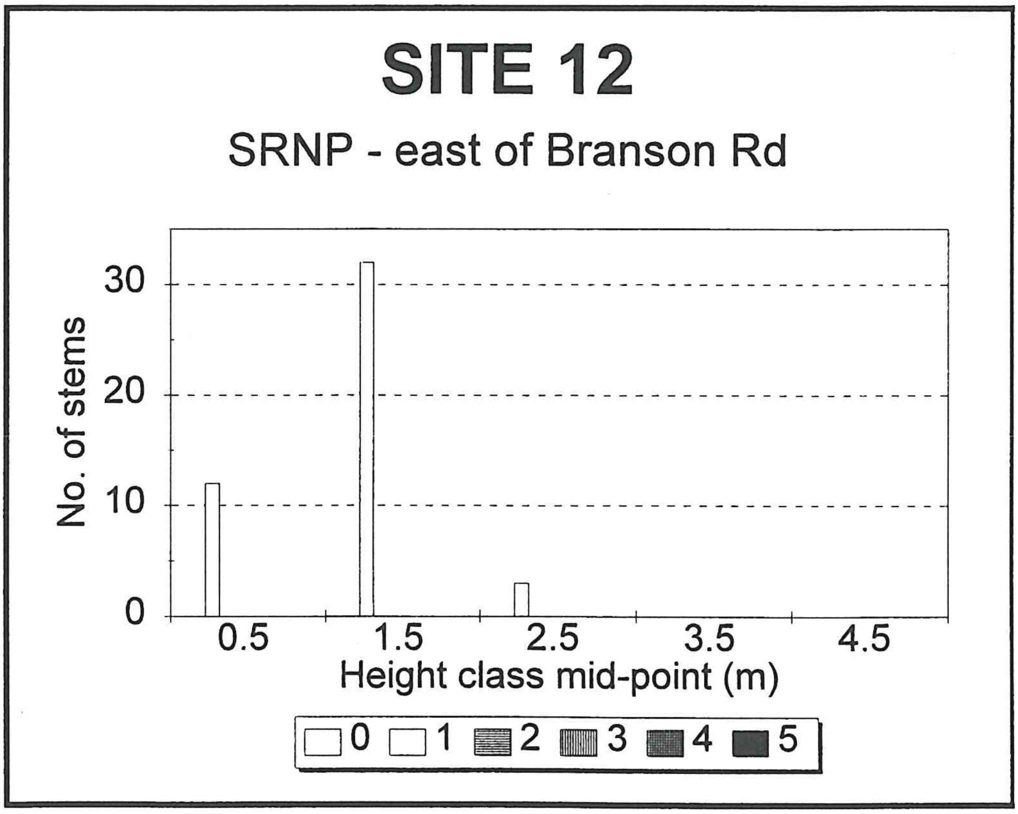

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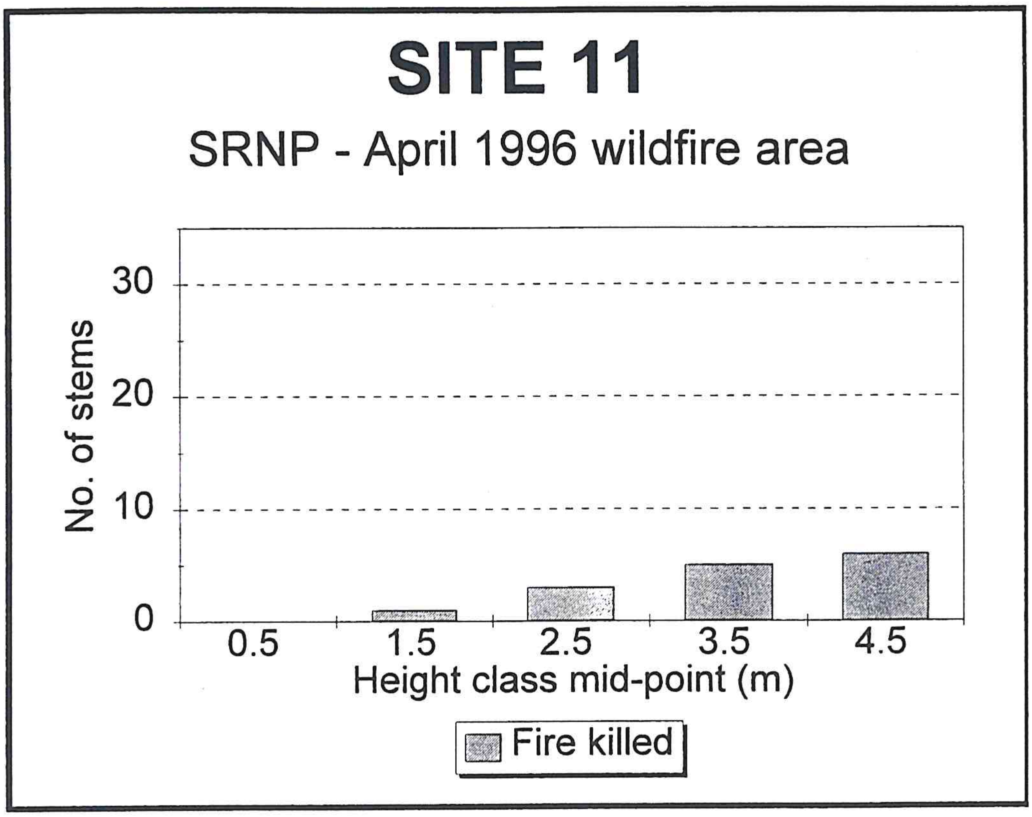

Figure 2. (cont.)

disease severity and stand age. Data are presented in the form of a histogram (Figure 3). Stands that were aged five years or younger showed slight, if any, limb dieback. Older stands showed various degrees of limb dieback, with about a quarter of those in the 10-15 year and 15-20 year age classes exhibiting severe (>50%) limb dieback. Of the additional sites in the over 20-year-old age class assessed in the present study, most carried only low levels (<10%) of limb dieback, while one third of stands in this age class exhibited moderate damage (10-50%) but none were severely affected.

4.2 SEEDLING REGENERATION FOLLOWING FIRE IN AN OLD STAND.

B. coccinea seedlings were counted in twelve, 2 m radius quadrats encircling mature individuals in an old stand of that species. The observed numbers of seedlings ranged between 0 (4 quadrats) and 32 with a mean value of 10.8 per quadrat (s.e. = 2.9).

4.3 GROWTH AND FLOWERING IN *B. COCCINEA*.

Data on plant height and flowering are presented in Table 2 for populations of *B. coccinea* that regenerated after fires in autumn, 1989 and spring, 1990. When initial measurements of plant height were made in spring, 1994 the former population was approximately six years old, whereas seedlings regenerating after the 1990 fire were three years of age, having appeared in early spring of 1991. Growth rates in both populations were similar with mean annual increments in stem height estimated at 0.13 m except for the 1994/95 growing season when growth rates were depressed by about 50% due to adverse climatic conditions.

The autumn 1989 cohort of seedlings flowered for the first time in 1994 with 65% of plants producing inflorescences. In the following year only one plant flowered, while in 1996 flowering was observed on 45% of the plants. One seedling from the spring 1990 cohort flowered for the first time in 1995, as did a second plant in 1996.

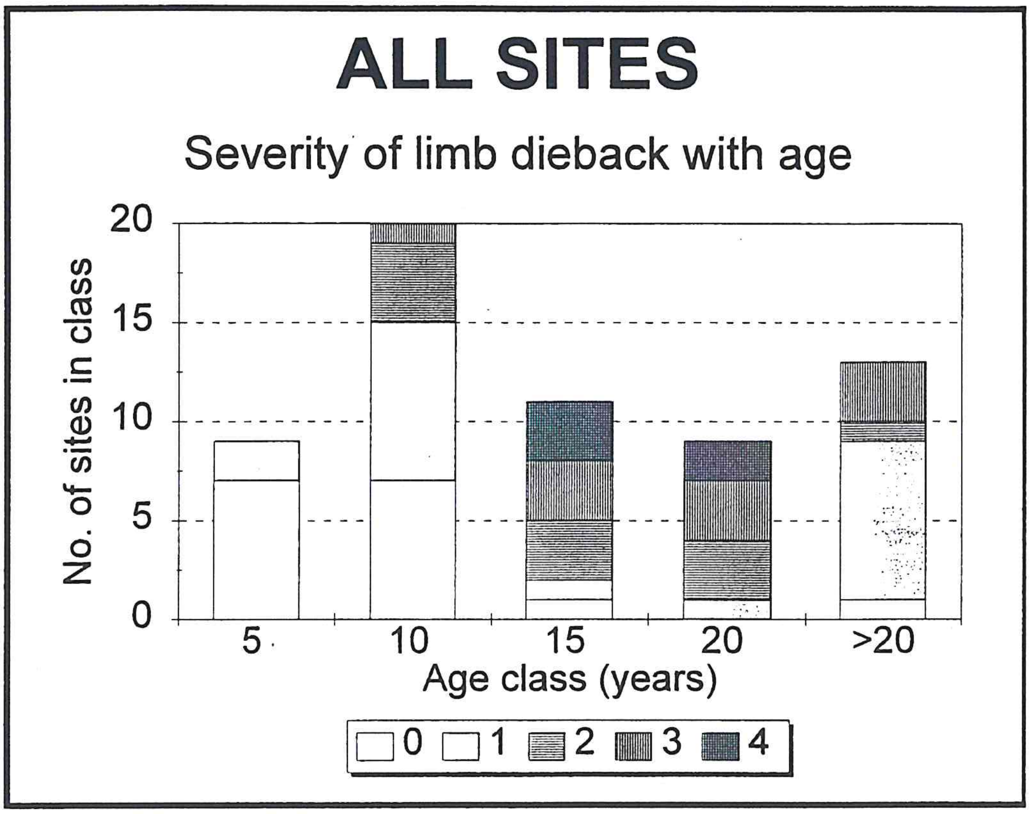

Figure 3. Frequency of *B. coccinea* stands grouped by age in five classes of severity of limb dieback. Limb dieback was described in severity classes of (0) no limb dieback, (1) <10%, (2) 10-25%, (3) 25-50%, (4) >50% of dead limb area per plant. Data from the present study have been combined with that of Bathgate and Shearer (1995).

Table 2. Plant height and proportions of plants in flower for cohorts of *B. coccinea* seedlings regenerated after fires in autumn 1989 and spring 1990. Plants were assessed in spring 1994, 1995 and 1996.

Year	1989 cohort		1990 cohort	
	Height (m)	% of plants flowering	Height (m)	% of plants flowering
1994	0.76	65	0.30	0
1995	0.83	5	0.36	0
1996	0.95	45	0.49	5

5 DISCUSSION

The results indicate that longevity of *B. coccinea* may exceed 45 years in the absence of disturbance by fire or severe infection by canker fungi. This contradicts Witkowski *et al.* (1991) who hypothesised that the natural lifespan of the species may be as short as 20 years. Although some evidence of interfire recruitement was observed here and by Witkowski *et al.* (1991) there is little doubt that even in the old, unburned stand, mature *B. coccinea* were the same age as other dominant shrub species which regenerated following the last fire. This is supported by the observed growth rates of young *B. coccinea* plants, which ranged between 0.06 m and 0.13 m/year. If an average growth rate of 0.1 m/year is assumed, then the 27-year-old and >45-year-old stands would be expected to consist mainly of 2-3 m tall and 4-5 m tall trees respectively. This was in fact the case as shown by the stand structures apparent at Sites 1, 2, 3, 4 and 11. The growth rate of *B. coccinea* might be expected to decline gradually with increasing plant age, and in the case of dense stands less thrifty individuals would become progressively suppressed by competition. This may explain the presence of many 1-2 m tall plants in the even-aged stands at Sites 2 and 3, with the mortality of smaller plants resulting from intense competition.

The considerable age of the stand at Site 11 (>45 years) did not prevent the successful, initial establishment of seedlings following fire. However, the long term success of regeneration is unpredictable due to the influence of various factors or agents including drought, grazing and plant disease.

Most of the stands exceeding 20 years of age were found to have only low levels of limb dieback. This finding is at variance with Bathgate and Shearer (1995) who found that the incidence of canker, the severity of limb dieback and the level of mortality were greatest in old stands of *B. coccinea*. The combined data set from both studies indicates that while limb dieback is uncommon in stands five years old or younger, the severity of disease in older stands may vary considerably. Insufficient sites were examined to fully investigate the effects of both stand age and geographic distribution on disease severity, but the pattern appeared to be similar at coastal and inland sites. Thus, increasing host age can only partly explain observed differences in disease incidence and severity between stands. Assuming that inoculum of *Cryptodiaporthe* is airborne and widely dispersed, it is difficult to explain the pattern of disease severity. Bathgate and Shearer (1995) recorded severely canker-degraded sites in the Stirling Range National Park, some of which were no more than 10-12 km to the west of Sites 1-3 from the present study. Strong winds from the north-west and west occur regularly in this area and these would seem to provide an excellent vector for the spread of inoculum. The patchy distribution of severely cankered stands presumably reflects the influence of currently unidentified factors.

Bathgate and Shearer (1995) identified the adverse effect of canker on seed production in *B. coccinea* and highlighted the requirement to utilise the existing seed store to establish regeneration in stands severely affected by *C. melanocraspeda*. Prescribed fire has a very important role in south coastal shrublands, providing protection against extensive wildfires and the opportunity to create mosaics of different aged vegetation. In the larger national parks and nature reserves prescribed burning is undertaken with the objective of creating mosaics within large blocks defined by existing roads and tracks. In this context, selection of individual stands of *B. coccinea* for particular treatment can present operational difficulties. However, the overall condition of *B. coccinea* stands within a block could be used as one criterion for determining prescribed burning regimes. There may be greater opportunity to manage fire specifically in regard to disease management objectives for smaller reserves where individual stands can be defined and incorporated into the planning process.

Time to first flowering was found to differ even between stands at the same location. Adverse seasonal conditions during 1994/95 reduced the growth rate of *B. coccinea* seedlings and prevented flowering of seven-year-old plants, many of which had flowered in the previous year. During 1994, annual rainfall for this region of Western Australia was in the lowest 10% on record (Bureau of Meteorology 1994).

6 OUTCOMES

- This study has demonstrated that the longevity of *B. coccinea* may exceed 45 years.

- Old stands of *B. coccinea* that have not suffered serious limb dieback and cone loss are capable of regenerating from seedfall following disturbance by fire.

- Stands less than six years old are unlikely to exhibit limb dieback as a result of canker. The severity of limb dieback in older stands is highly variable and cannot be explained solely in terms of stand age. A number of stands older than 20 years were only affected by limb dieback to slight degrees.

- Growth rates and plant age at first flowering may differ between adjacent populations of *B. coccinea* due to seasonal conditions. Time required for first flowering was at least six years for a population at the eastern end of the Stirling Range National Park. Plants in an adjacent population will require at least seven years to flower.

- The stands examined in the present study have been permanently marked and can provide a baseline for change in condition over time. Periodic re-assessment of these stands could provide valuable information about the spread and intensification of canker disease.

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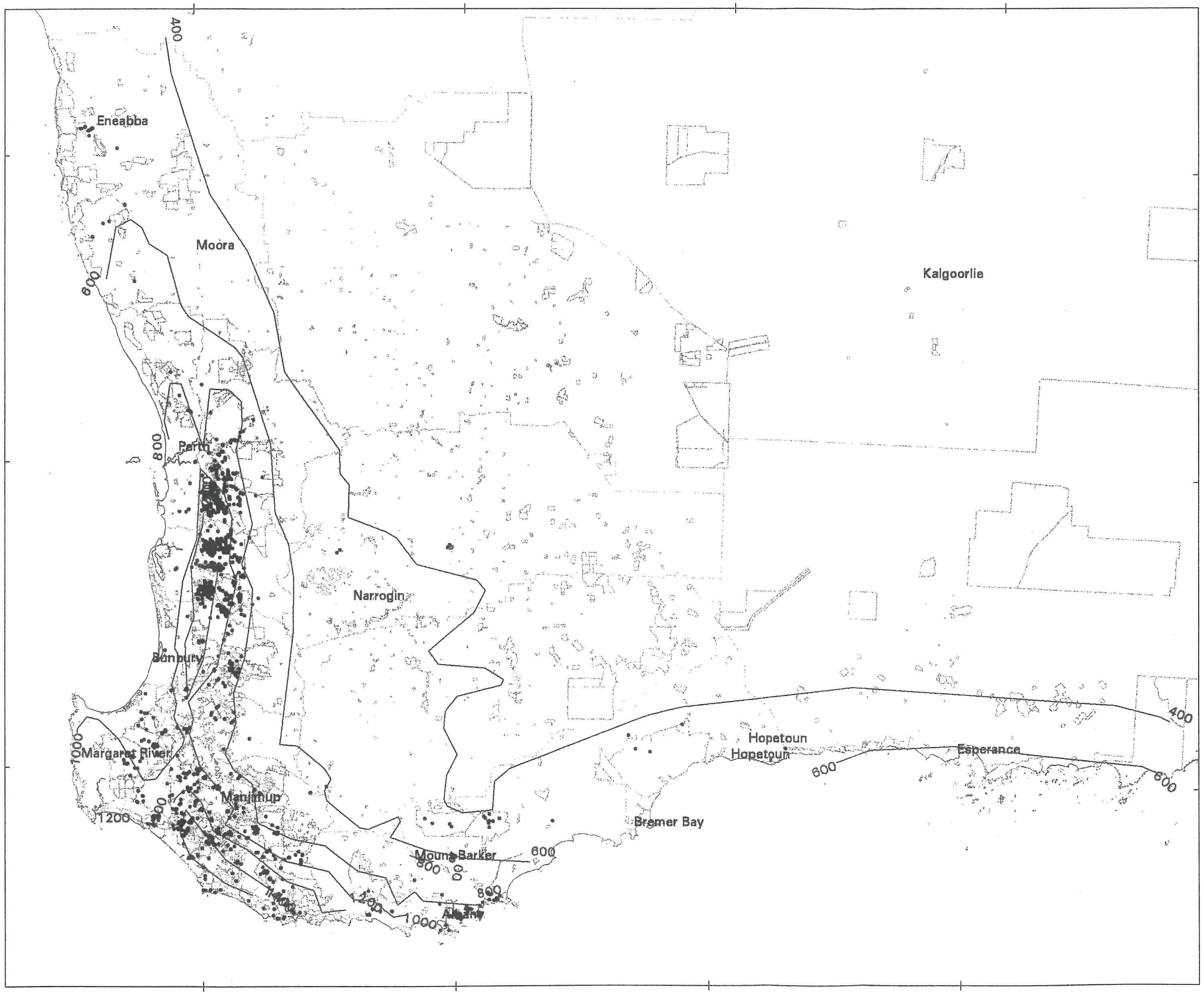
APPENDIX A

LOCATION DETAILS FOR TRANSECTS ESTABLISHED TO MONITOR STAND STRUCTURE AND CONDITION OF *B. COCCINEA* IN 1996

SITE	LOCATION	LAT/LONG	COMMENT
1	Stirling Range N. P.	34° 28.655 S 118° 16.117 E	On South East Track approx. 1.8 km east of track to Arnold's farm.
2	Stirling Range N. P.	34° 28.300 S 118° 15.700 E	Directly east of scrub-rolled buffer strip opposite the north-east corner of fire research plot no. 14.
3	Stirling Range N. P.	34° 28.083 S 118° 15.508 E	On the southern side of fire research plot no. 6.
4	Stirling Range N. P.	34° 28.530 S 118° 02.000 E	Approx. 2.5 km west of West Chester Track on innermost (northern) fire access track.
5	Hopetoun	33° 53.054 S 120° 25.785 E	South side of Springdale Road, approximately 26 km east from junction of Springdale and Ravensthorpe-Hopetoun Road.
6	Hopetoun	33° 55.982 S 120° 08.167 E	Table Hill, north of Hopetoun townsite. Located on fire access track east of navigation tower.
7	Wellstead	34° 31.640 S 118° 44.145 E	
8	South Stirling	34° 39.562 S 118° 12.437 E	On western side of South Stirling Road between Hassell Highway and South Stirling townsite. No transect established.
9	Chillinup Road	34° 34.049 S 118° 18.957 E	North of Chillinup Road on an embankment of white siliceous sand.
10	Waychinicup	34° 53 S 118° 24 E	On track heading south from Cheyne Beach to Mermaid Point. Stand is on south-westerly aspect overlooking the ocean.
11	Stirling Range N. P.	34° 28.531 S 118° 00.368 E	On innermost (northern) fire access track, approximately 30.3 km east from junction with South Talyuberup Track.
12	Stirling Range N. P.	34° 28.547 S 118° 18.517 E	On South East Track approximately 1 km in from the end of Branson Road.

Dieback Decision Support Tools

Figure 1. Location of *Phytophthora cinnamomi* isolates



Legend

- *Phytophthora cinnamomi* isolates (1698 points)
  Note that these points are drawn from the Vegetation Health Service and Northern Sandplains databases and do not necessarily indicate the total distribution of *P. cinnamomi*.
- CALM district boundaries
- CALM Estate
- Average annual rainfall isohyets

Kilometres

0 20 40 60 80 100 200

N S E W

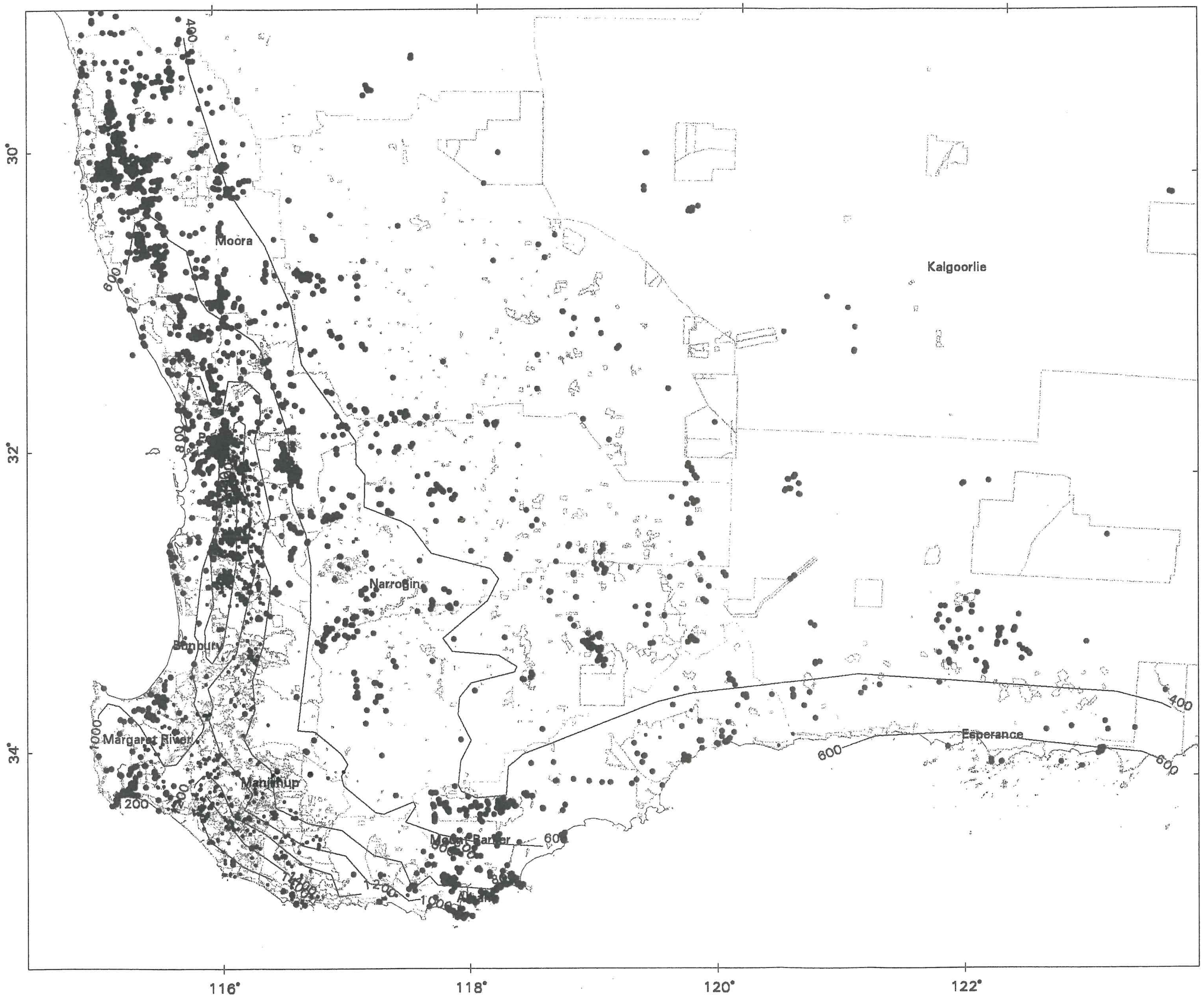
Map by Paul Gioia,
Science and Information Division, CALM

Dieback distribution data courtesy of Vegetation Health Service and Northern Sandplains Dieback Working Party)

22 April, 1997 at 2:20 PM

Dieback Decision Support Tools

Figure 2. Distribution of threatened/priority flora presumed susceptible to *P. cinnamomi*



Legend

- Threatened/priority flora populations (4797 points)
  Note that these points represent flora populations from the families *Myrtaceae, Proteaceae, Epacridaceae Papilionaceae* only.
- *Phytophthora cinnamomi* isolates (1698 points)
  Note that these points are drawn from the Vegetation Health Service and Northern Sandplains databases and do not necessarily indicate the total distribution of *P. cinnamomi*.
- CALM district boundaries
- CALM Estate
- Average annual rainfall isohyets

Map by Paul Gioia,
Science and Information Division, CALM

Dieback distribution data courtesy of Vegetation Health Service and Northern Sandplains Dieback Working Party)

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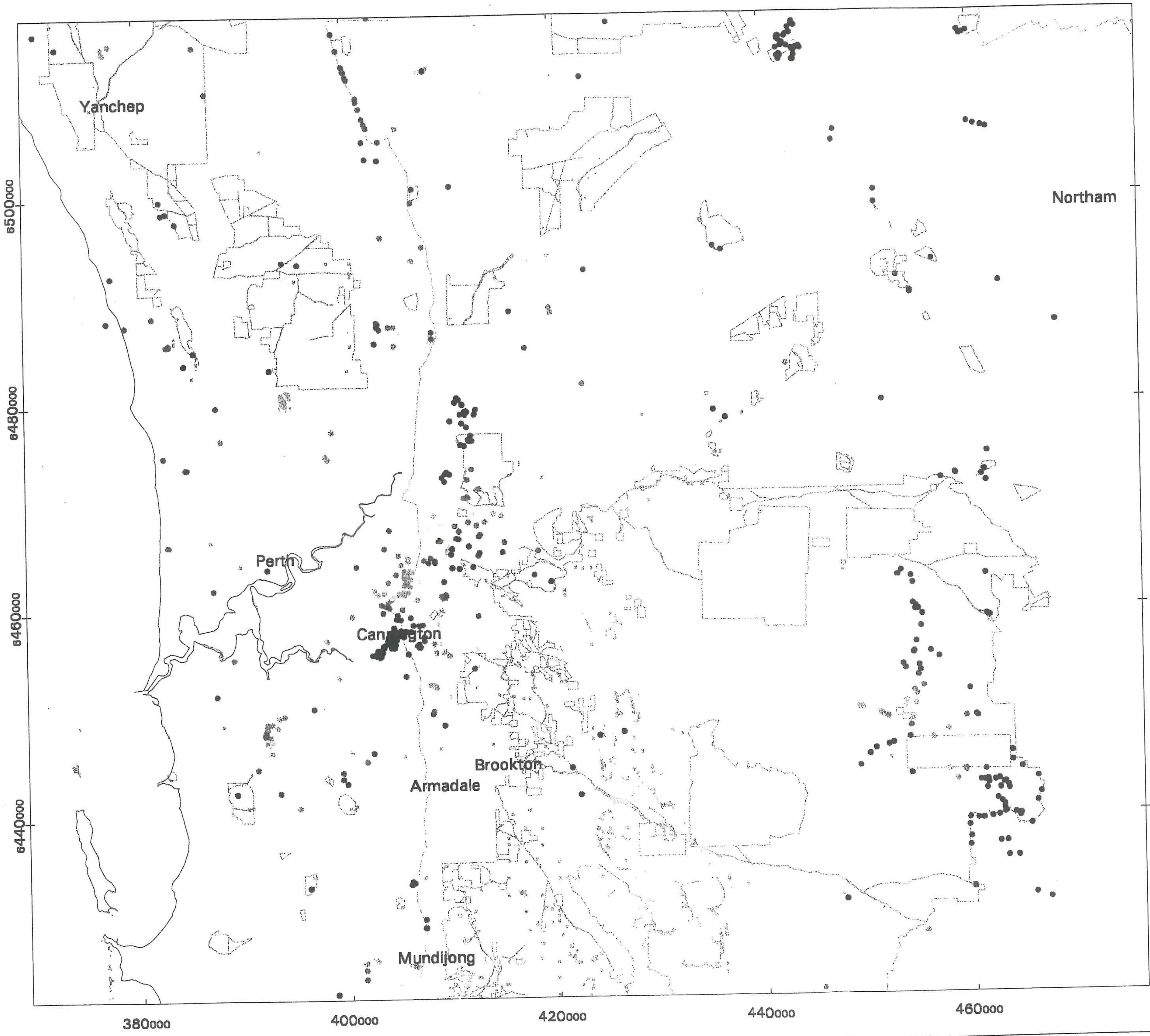
Dieback Decision Support Tools

Figure 3. Threatened/priority flora presumed susceptible to *P. cinnamomi*
Proximity-To-Dieback Analysis



Legend

- Populations within 500m of dieback (These populations might warrant phosphonate application)
- Populations up to 10km away from dieback (graduating from red to yellow - these populations might be considered safe from immediate threat but close enough to still warrant further protection or other management to prevent infection)
- Populations more than 10km from dieback (graduating from yellow to green - these These populations are probably far enough away from dieback to not warrant specific protection)
- CALM district boundaries
- CALM Estate
- Dieback distribution (FMIS pre and post 76, Swan and Bunbury vectors, VHS and Shearer points)

Note that these points represent flora populations from the families *Myrtaceae*, *Proteaceae*, *Epacridaceae* and *Papilionaceae* only.

Kilometres

0 2 4 6 8 10 20

N W E S

Map: AMG Zone 50, by Paul Gioia,
Science and Information Division, CALM

Dieback distribution data courtesy of Forest Management Branch (Swan, Central and Southern Forest Regions), Science and Information Division (Vegetation Health Service, Bryan Shearer) and the Northern Sandplains Dieback Working Party.

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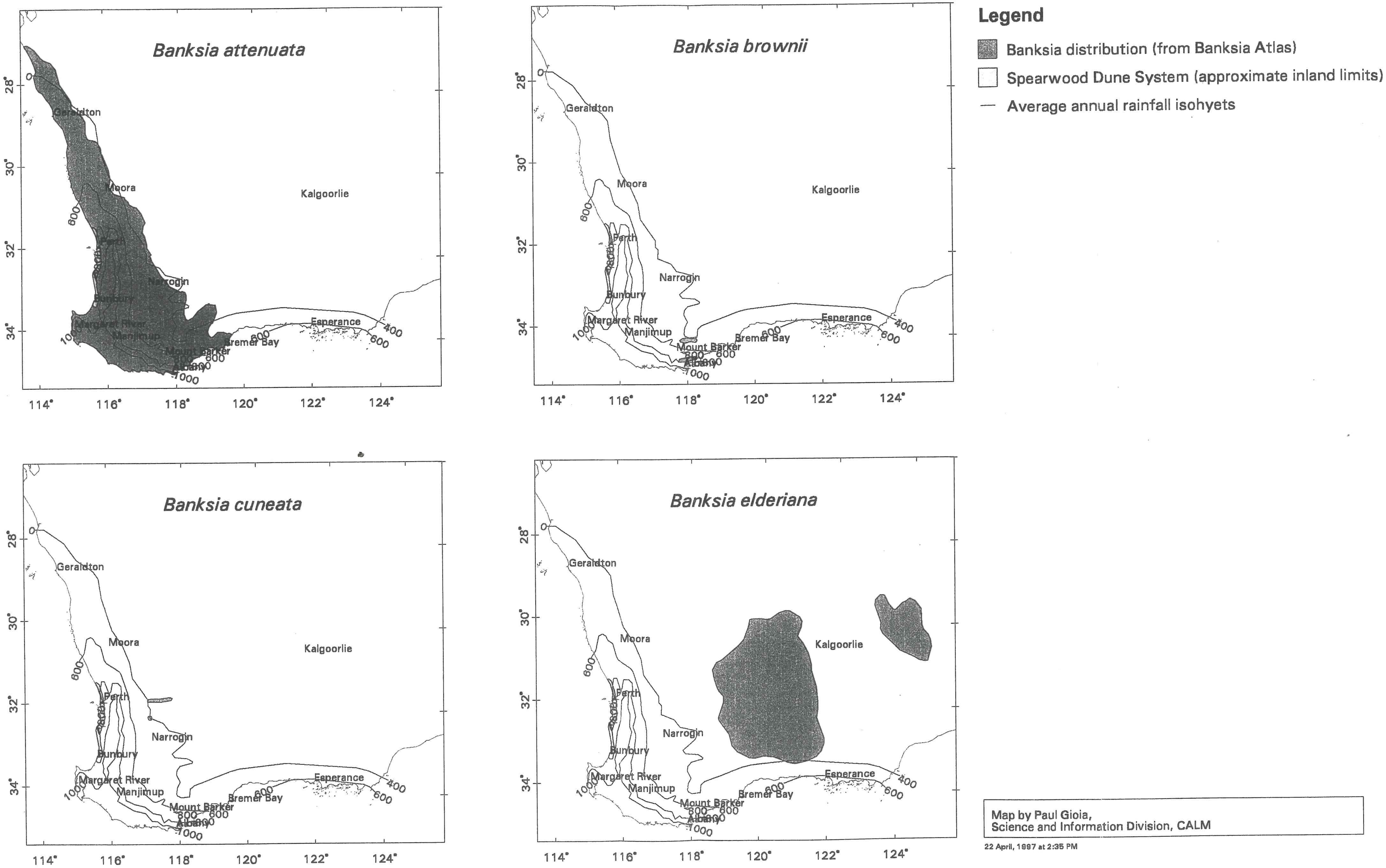
Figure 4. Alternative management scenarios for dieback-susceptible taxa



Map by Paul Gioia,
Science and Information Division, CALM

22 April, 1997 at 2:35 PM

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

FINAL REPORT

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

MAY 1997

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Environment Australia
Biodiversity Group