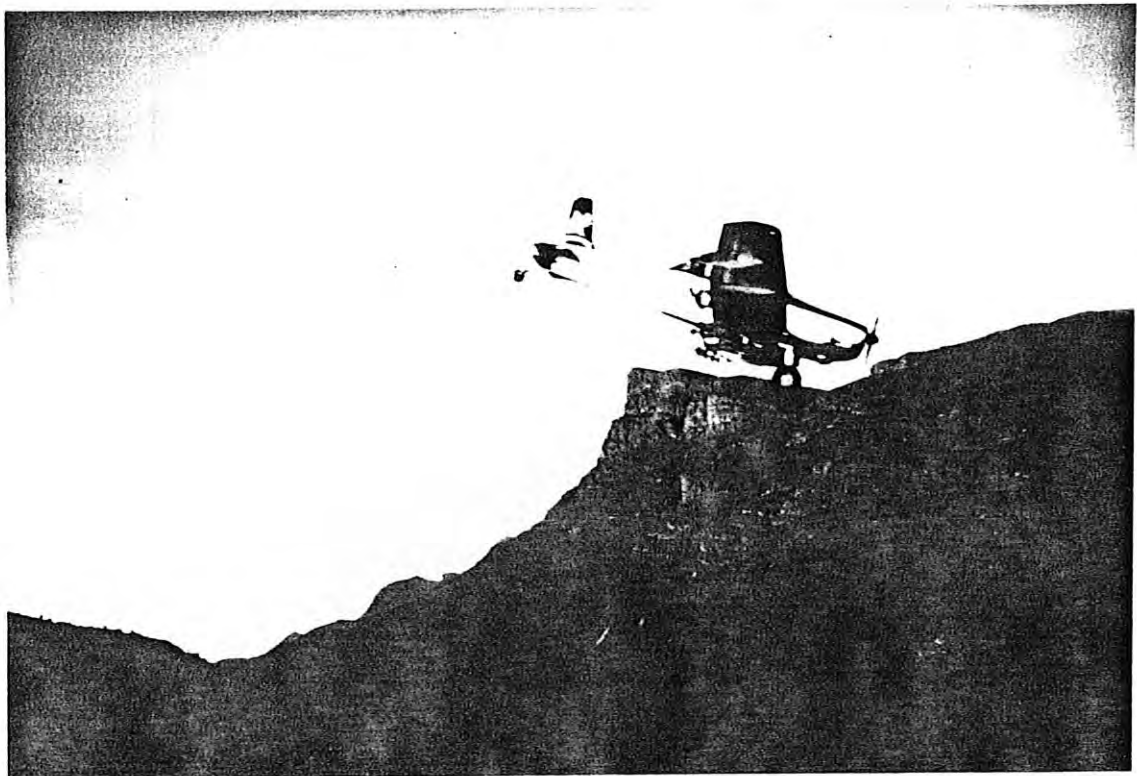




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AERIAL APPLICATIONS OF PHOSPHITE IN THE SOUTH COAST REGION OF WESTERN AUSTRALIA



Final report prepared by Sarah Barrett, Department of
Conservation and Land Management, Western Australia to the
Threatened Species and Communities Unit Biodiversity Group
Environment Australia

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AERIAL APPLICATIONS OF PHOSPHITE IN THE SOUTH COAST

REGION OF WESTERN AUSTRALIA

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Final Report by Sarah Barrett

Department of Conservation and Land Management

South Coast Regional Office, Albany

In conjunction with Environment Australia

June 1999

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The views and opinions expressed in this report are those of the author and do not represent those of the Commonwealth Government, the Minister for the Environment, Sports and Territories, the Director of Parks and Wildlife or the Executive Director of the Department of Conservation and Land Management.

The report may be cited as: Aerial Applications of Phosphite in the South Coast Region of Western Australia

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ABSTRACT

Aerial phosphite application at 24 kg ha⁻¹ resulted in significantly higher percentage survival of Phytophthora susceptible species in sprayed compared with unsprayed quadrats in Phytophthora-free vegetation on a dieback front at Bell Track South (Fitzgerald River National Park). Percentage survival in sprayed plants decreased from 18 months to two years post spray however it still remained significantly higher than that of control plants.

In Phytophthora-infested vegetation at Bluff Knoll in the Eastern Stirling Range Montane Community, percentage survival was also significantly higher in sprayed compared with unsprayed quadrats. While there was considerable decline in numbers in sprayed quadrats in the first year post spray there was no decline from 18 months to two years post spray.

Initial in planta phosphite concentrations and the subsequent decline in these concentrations varied with site. The epacrid species, Sphenotoma sp. Stirling Range from Bluff Knoll had considerable higher phosphite concentrations at two weeks and five months post-spray than the proteaceous species Dryandra cirsioides (Bell Track North) and Lambertia inermis (Bell Track South). Contributing factors may include differences in leaf surface characteristics, plant canopy cover and plant growth rates.

Further monitoring of phosphite applications is needed to determine the frequency and rate of phosphite application necessary to ensure disease control in plant communities of varying growth rates, structure and species composition.

In planta phosphite concentrations in unwashed samples of D. cirsioides and L. inermis were 15-20 times higher than those of washed samples indicating that a significant proportion of phosphite was not taken up from leaf surfaces. An alternative adjuvant to the surfactant Synetrol used in this study may improve chemical uptake in proteaceous species.

The majority of species in this study showed minimal phytotoxicity symptoms after phosphite application at 24 kg ha⁻¹. The most common symptom was partial to complete foliar necrosis. Greater sensitivity to phosphite was evident in the Myrtaceae and particular members of the Epacridaceae and Proteaceae.

Phytotoxicity was also expressed as growth abnormalities which were evident in 11% of the species assessed. These included 'little leaf' syndrome and rosetted foliage similar to that of zinc deficiency symptoms, as well as elongate or spindly foliage. Growth abnormalities were most common in members of the Proteaceae and in species growing on sandy soils at the Bell Track South site. Foliar chlorosis was evident in 7.5% of species assessed and commonly occurred in association with growth abnormalities. Differences between sites may reflect an effect of the low nutrient status of plants growing on sandy soils.

Phosphite application in autumn was associated with reduced flowering the following spring in two species assessed at Bell Track South. This reduction in flowering may have been a result of tip defoliation or a hormonal or nutritional influence. Potential effects on plant reproduction should be taken into consideration when spraying species with limited seed banks.

Increments in plant height were monitored in seedlings at Bluff Knoll and no significant effects on plant growth were observed.

*Consideration of the largely short-term effects of phosphite on plant health must be balanced by the threat to the survival of individual species and plant communities posed by *Phytophthora cinnamomi*, in particular the threat to those species or communities that are 'Critically Endangered' as a direct result of the pathogen.*

1. INTRODUCTION

This report details the results of an operational spray of a *Phytophthora cinnamomi* infection in the Bell Track area (210 ha) of the Fitzgerald River National Park and of the summit area of Bluff Knoll (15 ha) in the Stirling Range National Park. The project commenced in October 1996 and was funded by Environment Australia until May 1998. Further monitoring in spring 1998 and autumn 1999 was funded by the Department of Conservation and Land Management.

A report of additional research on phosphite phytotoxicity conducted by S. Barrett as part of a PhD at Murdoch University (Supervisors: Dr Bryan Shearer, Dept. Of Conservation & Land Management; Dr Giles Hardy, Murdoch University) will be presented in the thesis.

Research by Komorek *et al.* (1995) has developed aerial application techniques for phosphite which now makes feasible the spraying of whole plant communities either in areas currently infected by *Phytophthora cinnamomi*, in particular localised infections, or along a dieback front to protect dieback-free vegetation. Thus the chemical can become an important element of an integrated control strategy. Research trials have been targeted at determining the application rates which result in phosphite levels that effectively control the pathogen over the greatest time frame without compromising plant health. Phosphite applied at concentrations of 40% at a rate of 30-60 l/ha in two separate sprays with a final output of 24- 48kg a.i. ha⁻¹ result in phosphite concentrations expected to ensure control of infection for two to three years (Komorek *et al.* 1997).

While phosphite has been found to increase the resistance of a range of native plant species to *Phytophthora cinnamomi* in dieback-free vegetation behind a dieback front, the ability of the chemical to improve plant survival rates needs to be tested in a range of infected areas.

Phosphite application at 24kg a.i. ha⁻¹ has resulted in disease control for up to two years (Komorek *et al.* 1997), it is considered that application of 24 kg ha⁻¹ will ensure disease protection lasting up to three years due to the high initial levels of phosphite attained in plant tissue. This may vary in different plant communities and in vegetation of ages. Recent research (Komorek and Shearer 1998) indicates that faster growing young plants may lose their resistance to *P. cinnamomi* after phosphite application at 24kg ha⁻¹ within three years. *In planta* phosphite concentrations may also vary between species and decline at different rates.

While phosphite is considered to have low toxicity to plants (Guest & Grant, 1991) evidence of phytotoxicity has been reported in a range of horticultural species (eg Anderson & Guest, 1990; de Boer & Greenhalgh, 1990; Seymour *et al.*, 1994; Walker, 1989; Wicks & Hall, 1990). Symptoms of phytotoxicity included marginal to complete leaf burn, leaf shedding and growth abnormalities. Recent phosphite trials have observed phytotoxicity in a few native species (Gillen & Grant, 1997; Jackson, 1997; Komorek *et al.*, 1997; Bennallick, 1985), however much of the research to date has focussed on *Banksia* species and *Eucalyptus marginata*. Individual species may vary in their response to phosphite and their subsequent recovery from phytotoxicity incurred by phosphite (Bennallick, 1995). The affects of broad-scale application of a given concentration of phosphite are unknown at the species, genus or family level. It

is necessary to investigate the effect of phosphite on a broad range of species before using the fungicide more widely.

The aims of this project were:

1. To investigate the effectiveness of phosphite both in controlling the spread of the *P. cinnamomi* to non-infected vegetation, and in preventing further species decline in infected areas thus promoting the rehabilitation of infected vegetation.
2. To assess *in planta* phosphite concentrations in selected species following phosphite application and subsequent decline in phosphite levels.
3. To investigate any phytotoxic side effects of phosphite in the communities sprayed.

2. METHODS

2.1 Description of the study area

The three sites occur within the south coast region of Western Australia (Fig 2.1). Bell Track North (S33°52'58" E119°29'16") and South (S33°54'31" E119°29'26") are in the Fitzgerald River National Park, a UNESCO Biosphere Reserve which is located between Albany and Esperance. The Bluff Knoll site (S 34°22' 32" E118°15'17") is located on the summit area of Bluff Knoll within the Critically Endangered Eastern Stirling Montane Heath and Thicket Community (Barrett 1999), Stirling Range National Park (Fig 2.2).

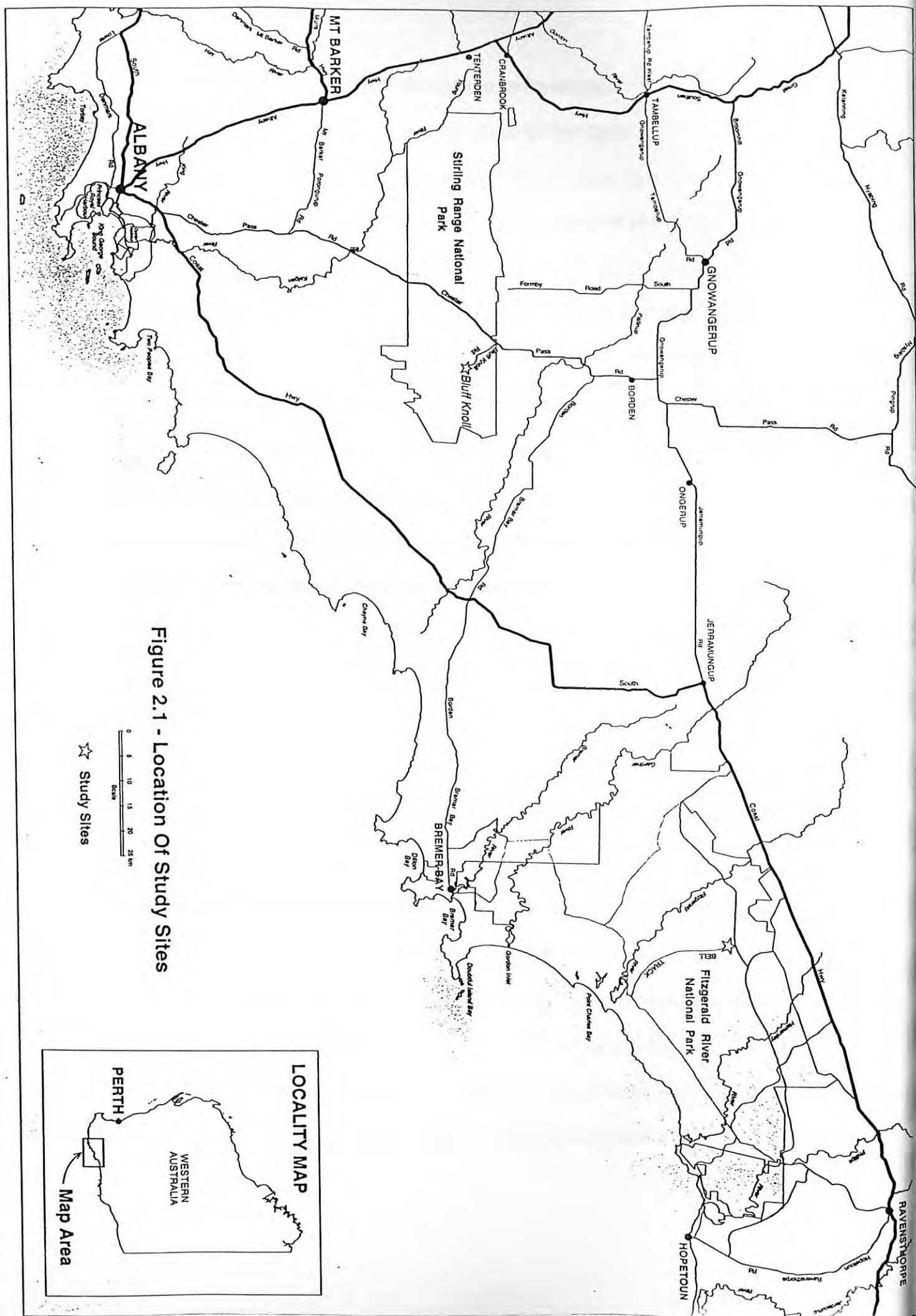
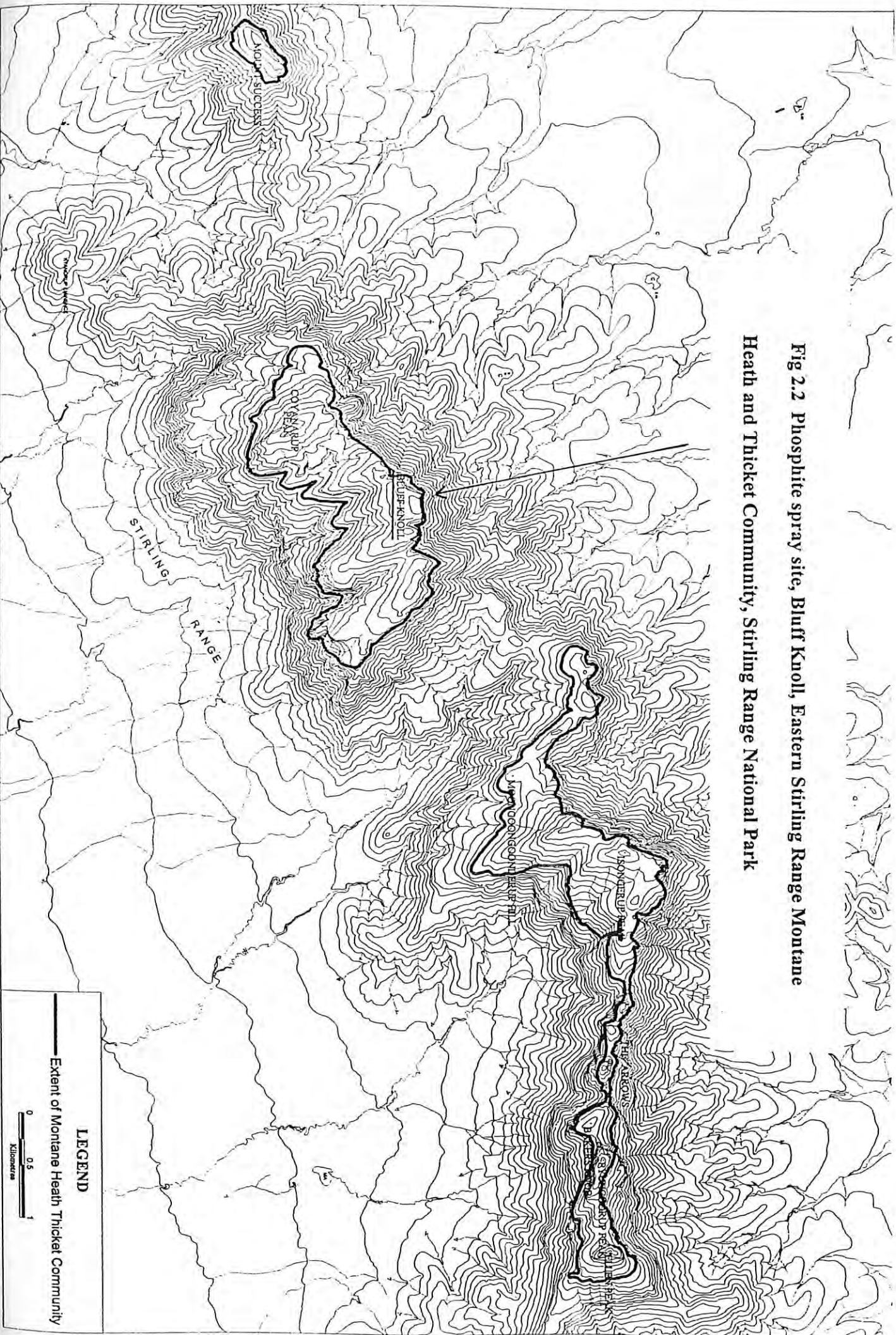


Figure 2.1 - Location Of Study Sites

Fig 2.2 Phosphite spray site, Bluff Knoll, Eastern Stirling Range Montane Heath and Thicket Community, Stirling Range National Park



2.2 Establishment of monitoring quadrats

Plot size was selected to ensure that sufficient numbers of *Phytophthora* susceptible species were present to permit monitoring of species decline over time. In each quadrat all the species present were recorded and the average percentage canopy cover of diseased or necrotic foliage pre-spray.

Bell Track Site

Monitoring plots were established both behind and in front of the dieback front in two plant communities. These were very open mallee over heath vegetation on loamy sand and gravel in Bell Track North (Fig 2.4), and in thicket and scrub on deep sands in Bell South (Fig. 2.5). Six 5m x 5m plots were established within dieback-affected vegetation, and six 5m x 5m plots in non-infected vegetation on the dieback front. Control plots were established in both communities using the same methodology and excluded from the spray.

Bluff Knoll

Monitoring quadrats were established at Bluff Knoll in dieback-infected dwarf scrub vegetation on shallow sandy clay loam (Fig 2.6). The site was regenerating from a fire in 1991. Plot width was 1m and plot length 5m. Six quadrats were established per treatment and control. The control plots were covered with clear plastic during phosphite application.



Fig. 2.4 Mallee-heath, Bell Track North, Fitzgerald River National Park



Fig 2.5 'Dieback front' Bell Track South, *Phytophthora* infested vegetation (foreground) and *Phytophthora* free vegetation (background).



Fig. 2.6 *Phytophthora cinnamomi* infested vegetation on Bluff Knoll, Stirling Range National Park

2.3 Phosphite application

A rate of 24kg ha⁻¹ was selected for operation use as minimal phytotoxicity symptoms were observed at this rate in earlier trial aerial phosphite applications at three rates (24, 36 and 48 kg ha⁻¹). Operational sprays were conducted by Giles Aviation, using a Cessna Agwagon 188B equipped with a Micronair Rotary Atomiser spray system that resulted in a droplet size between 300-500 μ m, with coverage of approximately 60 droplets cm⁻². The spray formulation was applied from an altitude of 10m above the plant canopy in 15m wide swathes, at a rate of 30l ha⁻¹ using 40 % phosphite (Foli-R-fos 400). One application of 40% product applied at an equivalent rate of 30l ha⁻¹ resulted in an output of 12kg a.i. ha⁻¹. The initial aerial application was followed up by a second application six weeks later to achieve a final output of 24kg ha⁻¹. Synertril Oil, a vegetable oil concentrate, was added as a surfactant at a rate of 2% of total volume. Synertril maximises phosphite uptake by aiding the formation of uniformly sized spray droplets, increasing droplet deposition, droplet spread and by reducing evaporation or removal by rainfall. Spraying was conducted in low wind speed conditions (< 10 knots) to minimise spray drift. Spraying for all trials occurred between early to mid-morning at temperatures less than 30°C.

2.4 Monitoring the survival of *Phytophthora* sensitive species

Two weeks post-spray in May 1997, numbers of key *Phytophthora* susceptible species were counted in both dieback-affected and dieback-free plots to monitor survival rates over time (Table 2.1). Plots were reassessed in October 1997, March 1998, November 1998 and April 1999.

At the Bell Track South site, due to the low numbers of any one dieback-susceptible species present in infected vegetation, several species from the Proteaceae and Epacridaceae were used to monitor species recovery or decline. At the Bluff Knoll Site, due to the difficulty of reliably distinguishing *Andersonia axilliflora* seedlings from *A. echinocephala* seedlings, data from the two species were combined.

Photographic monitoring was also conducted at each site.

Table 2.1 *Phytophthora* susceptible species monitored for survival

	Bell Track South	Bell Track North	Bluff Knoll
<i>Phytophthora</i> -free	<i>Banksia baxteri</i> <i>Lambertia inermis</i>	<i>Dryandra cirsioides</i> <i>B. violacea</i> <i>B. caleyi</i> <i>Isopogon buxifolius</i> <i>Xanthorrhoea platyphylla</i>	-
<i>Phytophthora</i> present	Species present from the families Proteaceae and Epacridaceae	<i>Dryandra cirsioides</i> <i>B. violacea</i> <i>B. caleyi</i> <i>Isopogon buxifolius</i> <i>Xanthorrhoea platyphylla</i>	<i>Sphenotoma</i> sp. Stirling Range; <i>Andersonia axilliflora</i> and <i>A. echinocephala</i> .

2.5 Phosphite analysis and sampling

Both stem and leaf material of similar maturity and health, were sampled for phosphite analysis, replicate samples were taken from larger plants.

One species from each plant community was sampled for phosphite analysis two weeks after the second spray in May 1997, and in October 1997. These were *L. inermis* (Bell Track South), *D. cirsioides* (Bell Track North) and *Sphenotoma* sp.

Stirling Range (Bluff Knoll). Two replicate samples were taken from 12 tagged individuals of *L. inermis* and *D. cirsioides*. Due to the small size of *Sphenotoma* sp., single samples of 20 individuals were taken at each assessment. It was necessary to sample the entire above ground plant to ensure that the minimum required dry weight of 0.5 g was available for analysis.

Shoot and root material of *Lambertia inermis* was sampled in March 1998 from five of the 12 tagged individuals.

Samples were washed in warm water with a small amount of phosphate-free detergent to remove any phosphite from the surface of the leaves. These were then rinsed in warm water before being placed in paper bags and dried at 37°C in a low temperature oven to minimise potential oxidation. When dry, samples were ground using an electric grinding machine with a 1mm sieve and stored in 50ml screw cap containers. Between samples the machine was cleaned with pressurised air.

Specimens were transferred to 10ml polyethylene centrifuge containers and weighed to $0.5 \text{ g} \pm 0.002 \text{ g}$. Every 10 specimens a replicate sample was taken.

Phosphite analysis was also conducted on unwashed samples of *L. inermis*, *D. cirsioides* and *Sphenotoma* sp. from trial phosphite applications conducted from November 1996 to January 1997 prior to the operational applications. *In planta* phosphite concentrations in material sampled two weeks after the second trial spray was compared with phosphite concentrations in the same species two weeks after the second operational spray. The trial plots at Bell Track North and South were aerially sprayed as for the operational spray. The trial spray at Bluff Knoll utilised a low-volume hand held applicator, the "Microfit Herbi System" (Micron Sprayers Ltd).

Chemical analysis

4.5ml of 0.1N sulphuric acid added to each centrifuge tube and samples were shaken at 15 to 20 minute intervals over two hours. Samples were centrifuged for approximately 10 minutes at 8000 rpm and 250 μ l of the clear acid extract transferred into 5ml volumetric flasks. Seven tubes were prepared for a phosphite standard by adding 250 μ l of solutions containing 1, 5, 10, 50, 100, 500 and 1,000 μ g/ml phosphite to 1ml of methanol in 5ml volumetric flasks.

Samples were analysed by the Western Australian State Chemistry Centre along with two control samples of known phosphite content per 50 samples analysed. Diazomethane was added to the samples in excess until a persistent yellow colour was observed. Diazomethane was prepared using chemical Diazald and a Diazald kit to generate its solution in ethyl ether. Excess diazomethane was neutralised using a few millilitres of isopropanol and the solution transferred into vials for analysis. When diazomethane is added to the filtrate phosphorous acid is converted to dimethyl phosphite. The dimethyl phosphite content was analysed using gas chromatography utilising a P-sensitive column and a phosphorous-specific flame photometric detector. The limit of phosphite detection was 1 μ g/g dry wt material.

2.6 Monitoring of phytotoxicity

At two weeks post-spray all species within monitoring plots in *Phytophthora*-free vegetation at Bell Track South and North, and in infected vegetation at Bluff Knoll, were assessed for signs of phytotoxicity taking into consideration any foliar necrosis which was present pre-spray. Control plots were assessed for changes in

plant health at the same time. Phytotoxicity was rated using the following scoring system:

0 = zero necrotic foliage

1 = 1-20% of canopy affected -mild

2 = 21-40% of canopy affected - moderate

3 = 41 - 60% of canopy affected – moderately severe

4 = 61 - 80% of canopy affected - severe

5 = 81 - 100% of canopy affected - extreme

Further assessments were conducted in October 1997, March 1998 and November 1998. By the second assessment, defoliation was a major component of the phytotoxicity ratings as foliage with total leaf necrosis was progressively shed over summer. Vegetative resprouting and new shoot growth became apparent and phytotoxic symptoms including growth abnormalities of new foliage were noted in certain species. Phytotoxicity was subsequently scored as two components:

1) Phytotoxicity including percentage necrotic and deformed foliage

2) Percentage defoliation

Chlorosis was also noted in a range of species but was not included in the phytotoxicity rating, but it generally occurred in association with growth abnormalities.

Phytotoxicity rating data from each site were averaged over the four assessment sessions and the mean ratings of six (Bluff Knoll) and four (Bell Track North and South) monitoring quadrats were ranked to compare between species.

Plant growth

At the Bluff Knoll site 15 *Kunzea montana* plants were randomly selected and tagged in sprayed and control plots. Plant height was measured from tip to soil level at the time of spraying and monitored at subsequent assessments.

***Eucalptus* phytotoxicity**

Following observations of widespread foliar necrosis in eucalypt species post-spray at Bell Track North, 15 individuals of *Eucalptus redunca* were selected and tagged to monitor recovery of plant health.

Flower production

At Bell Track South, following observations of reduced flowering in sprayed plants within dieback-infected vegetation, 18 individuals of *Calytrix leschenaultia* and *Baeckea preissiana* were randomly selected and tagged in sprayed and control plots. Numbers of flowers per individual were counted in spring 1977 and 1998.

2.7 Statistical analysis

Percentage survival rates of *Phytophthora* susceptible species were estimated and data transformed by arcsin (x). Data were tested for assumptions of normality and analysed by means of factorial ANOVA with species and spray treatment as the independent variables and percentage survival as the dependent variable. Data from each site were analysed separately.

Height increment and flowering data were transformed by $\log(x+1)$. Where the assumption of homogeneity of variances was not met the significance level for ANOVA was reset at 0.01 (Tabachnik and Fidel 1996).

3. RESULTS

3.1 Monitoring the survival of *Phytophthora* sensitive species

By March 1998 a high level of disease activity was apparent on the unsprayed dieback front in previously uninfected vegetation at the Bell South site. Disease activity was obvious again in November 1998 and April 1999. Percentage survival of *B. baxteri* and *L. inermis* in November 1998, 17 months after phosphite application, were significantly ($p < 0.01$) higher in sprayed vegetation compared with the control (Fig 3.1a). By two years post spray (April 1999), percentage survival had decreased in sprayed plots but were still significantly ($p < 0.05$) higher than in control plots (Fig 3.1b)

Only low numbers of plant deaths were recorded in vegetation previously infected by *P. cinnamomi* at Bell Track South in both sprayed and unsprayed plots. Therefore there was insufficient data to analyse percentage survival rates.

Disease activity at the Bell Track North site was considerably less than at Bell Track South and no trends in plant mortality were evident.

At the Bluff Knoll site there was a significant ($p > 0.01$) difference between the survival rates of *P. cinnamomi*-susceptible species (*Sphenotoma* sp. Stirling Range and *Andersonia* spp.) in sprayed and non-sprayed plots in November 1998 (Fig 3.2a). The effect of species was not significant ($p > 0.05$). Plants deaths occurred in sprayed

plots as well as in control plots over the assessment period resulting in lower percentage survival than those of the Bell Track South species. At the final assessment in April 1999 no deaths were recorded in sprayed plots and percentage survival remained significantly ($p < 0.01$) higher compared with control plots (Fig 3.2b).

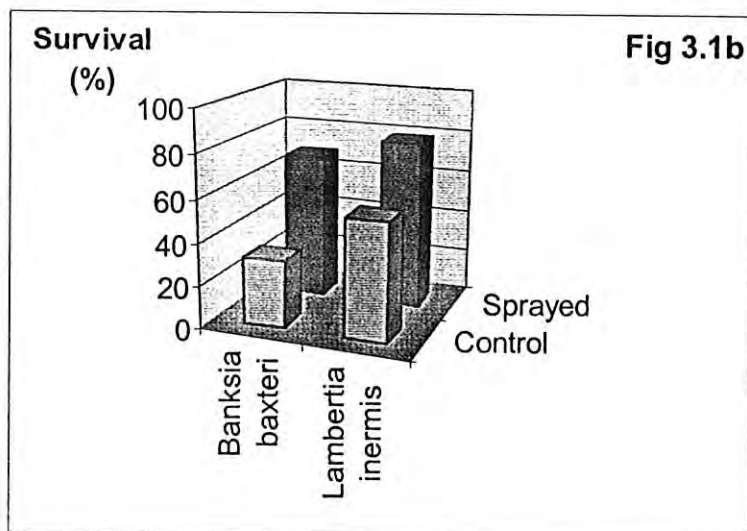
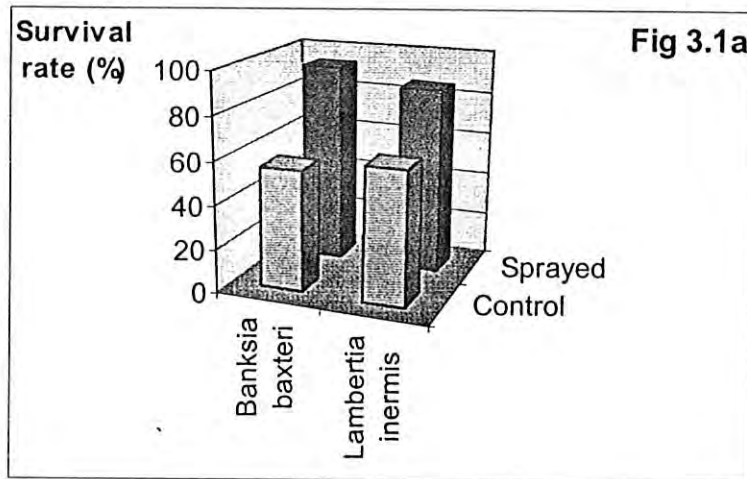


Fig 3.1. Mean percentage survival of *Phytophthora cinnamomi* susceptible species in monitoring quadrats on a dieback front, Bell Track South, Fitzgerald River National Park, a) May 1997 to November 1998 and b) May 1997 to April 1999. Data is mean of percentage survival from six quadrats.

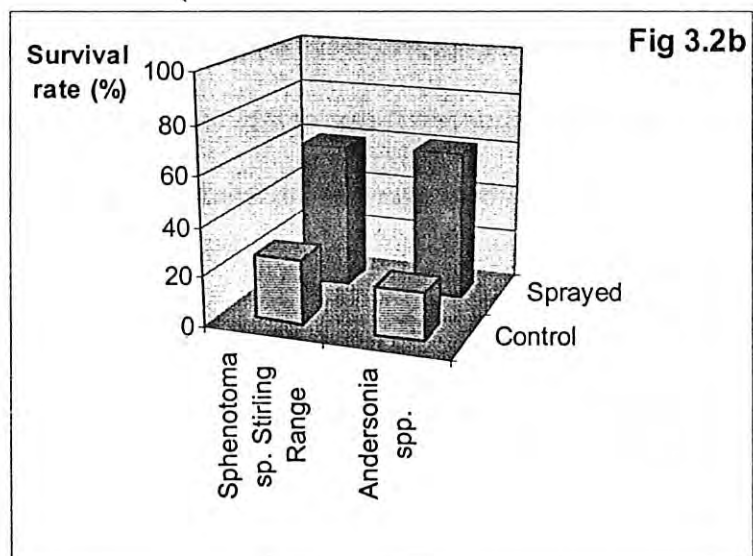
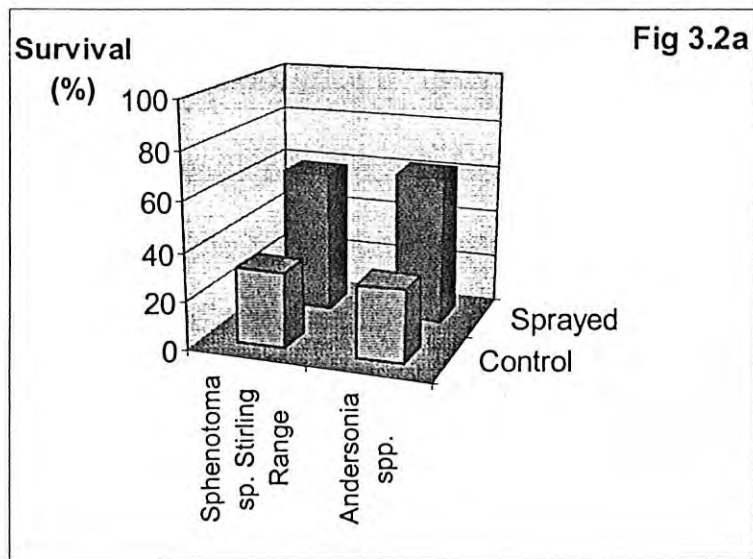


Fig 3.2 Mean percentage survival of *Phytophthora cinnamomi* susceptible species in sprayed and control quadrats within a dieback infection, Bluff Knoll, Stirling Range National Park, a) May 1997 to November 1998 and b) May 1997 to April 1999. Data is mean of percentage survival from six quadrats.

3.2 *In planta* phosphite concentrations

Two weeks after phosphite application at 24kg ha^{-1} , *in planta* phosphite concentrations in shoots were more than six times higher in *Sphenotoma* sp. Stirling Range (Bluff Knoll Site) than in *Lambertia inermis* (Bell South) and *Dryandra cirsioides* (Bell North) (Table 3.1). At five months post-spray levels had dropped to almost 25% of initial levels in *L. inermis* and *D. cirsioides* while those in *Sphenotoma* sp. were over 60% of initial concentrations.

At 10 months post phosphite application concentrations in *L. inermis* shoots had only dropped slightly from levels at five months. *In planta* concentrations in roots were over double those in shoots (Table 3.2).

Table 3.1. Mean phosphite levels in selected species two weeks after phosphite application at 24kg ha^{-1} and five months later. Data is the mean of 24 *Dryandra cirsioides* and *Lambertia inermis* and 20 *Sphenotoma* sp. samples $\pm$ standard error.

Species	Phosphite concentration (ppm)	
	May 1997	Oct/Nov 1997
<i>Sphenotoma</i> sp. (Bluff Knoll)	242.9 ± 31.3	154 ± 25.2
<i>Lambertia inermis</i> (Bell south)	38.2 ± 4.6	10.5 ± 1.7
<i>Dryandra cirsioides</i> (Bell north)	23.8 ± 1.6	6.6 ± 1.4

Table 3.2. Mean phosphite levels in *Lambertia inermis* shoots and roots 10 months after phosphite application at 24kg ha⁻¹. Data is the mean of 10 shoot and 5 root samples $\pm$ standard error.

<i>Lambertia inermis</i>	Phosphite concentration (ppm)
Shoots	8.3 $\pm$ 2
Roots	18.8 $\pm$ 10.9

In planta phosphite concentrations in unwashed samples of *L. inermis* and *D. cirsioides* from the trial sprays were more than 20 and 15 times, respectively, those of washed samples from the operational spray (Table 3.3). In contrast, concentrations in washed samples of *Sphenotoma* sp. were higher than those of unwashed samples.

Table 3.3 Mean *in planta* phosphite concentrations in washed and unwashed samples of *Lambertia inermis*, *Dryandra cirsioides* and *Sphenotoma* sp. Stirling Range two weeks after phosphite application at 24kg ha⁻¹. Values are the mean of 24 *L. inermis*, and, *D. cirsioides* and 20 *Sphenotoma* sp. samples $\pm$ standard error.

	Washed samples (Operational sprays May 1997)	Unwashed samples (Trial sprays December 1996 / January 1997)
<i>Lambertia inermis</i>	38.2 $\pm$ 4.6	817.1 $\pm$ 69
<i>Dryandra cirsioides</i>	23.8 $\pm$ 1.6	355.8 $\pm$ 37.5
<i>Sphenotoma</i> sp. Stirling	242.9 $\pm$ 31.3	212.2 $\pm$ 39.2
Range		

3.3 Monitoring of phytotoxicity

Phytotoxicity was most frequently expressed as foliar necrosis which ranged from tip and marginal necrosis to full leaf necrosis, depending upon the severity of the symptoms. The percentage of canopy affected also varied with the severity of the symptoms (Fig. 3.3, 3.4). Phytotoxicity was observed in 59.6% of the 146 species assessed (Appendix 1a-c). Symptoms were most common in the Myrtaceae (26.4%), Proteaceae (23%) and Epacridaceae (16%). Symptoms were in general mild (ratings $>0, \leq 1$) however moderate to moderately severe symptoms ($>1, \leq 3$) were observed in a range of species, particularly from Bell Track South (Table 3.4).

Table 3.4 Species in which moderate ($>1, \leq 2$) or moderately severe ($>2, \leq 3$) phytotoxicity ratings were recorded from Bell Track sites and Bluff Knoll.

Species	Phytotoxicity rating	Site
<i>Agonis spathulata</i>	2.5	Bell Track South
<i>Andersonia aff simplex</i>	1.7	Bell Track South
<i>Beaufortia micrantha</i> var <i>empetrifolia</i>	2	Bell Track South
<i>Baeckea preissiana</i>	1.3	Bell Track South
<i>Dryandra cuneata</i>	1.3	Bell Track South
<i>Isopogon trilobus</i>	1.3	Bell Track South
<i>Leucopogon conostephoides</i>	1.3	Bell Track South
<i>Lysinema ciliatum</i>	2.3	Bell Track South
<i>Melaleuca striata</i>	1.3	
<i>Petrophile longifolia</i>	1.3	Bell Track South
<i>Stirlingia tenuifolia</i>	3	Bell Track South
<i>Acacia myrtifolia</i>	1.5	Bell Track North
<i>Sphenotoma</i> sp. Stirling Range	1.3	Bluff Knoll
<i>Andersonia echinocephala</i>	1.3	Bluff Knoll



Fig 3.3 Partial necrosis of new growth in *Eucalyptus* at Bell Track North.



Fig 3.4 Moderately severe phytotoxicity with partial and full leaf necrosis in *Eucalyptus communalis* at Bell Track North

Growth abnormalities were apparent in 11% of the species assessed. These were most common in the Proteaceae (56%) followed by the Myrtaceae (31%). The most common growth abnormality was 'little leaf' (Fig 3.5) with or without rosetted or fasciculate foliage (Fig 3.6). This was accompanied in certain species by spindly, elongate shoot growth. (Fig 3.7) Chlorosis of foliage was observed in 7.5% of species, most frequently in the Proteaceae (36%) and Myrtaceae (36%). and commonly occurred in combination with growth abnormalities, in particular of expanding leaves (Fig 3.8).

Bell Track South

Of the 68 species assessed at the Bell South site, 41% had no symptoms. Averaged over the whole assessment period, 57% had mild phytotoxicity symptoms (mean ratings $>0, \leq 1$) and 4% had moderate symptoms (mean ratings $>1, \leq 2$) (Fig 3.9). Severe to extreme symptoms (ratings $>3, \leq 5$) were observed post spray in individuals of *Nuytsia floribunda* outside of assessment quadrats. However, by the final assessment at 17 months post-spray these individuals had demonstrated full vegetative recovery.

At the final assessment, 82.4 % of species had no symptoms and the remainder showed mild to moderate symptoms (mean ratings $>1, \leq 2$) (Fig 3.10).

Growth abnormalities were apparent in 16.2% of species and chlorosis in 8.8% of species (Table 3.5). At the final assessment, growth abnormalities persisted in 10.3% of species and chlorosis in 8.8% of species (Table 3.11). 'Little leaf' was particularly persistent in *Isopogon trilobus* and small and chlorotic foliage conspicuous in *Petrophile phyllicoides* and *Lysinema ciliatum*. An abundance of new growth was apparent in *B. baxteri* in sprayed compared with non-sprayed plants, some

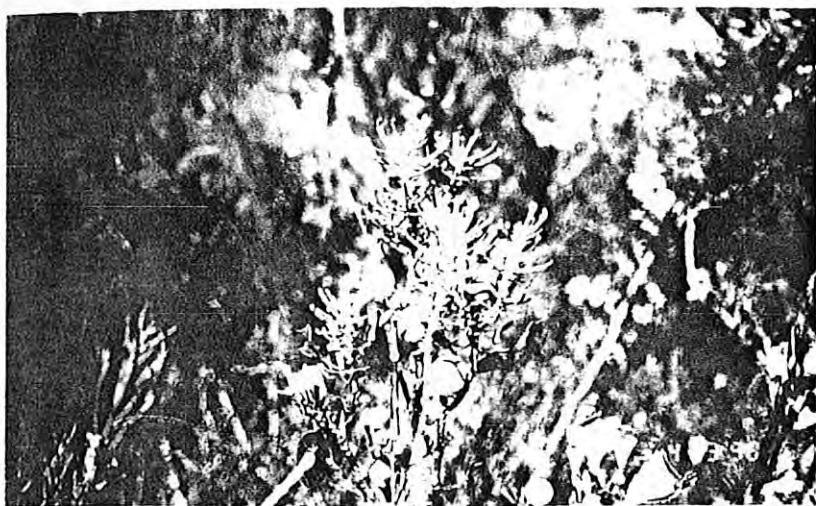


Fig. 3.5 'Little leaf' symptoms in new growth of *Isopogon trilobus*, Bell Track South



Fig. 3.6 Fasciculate / rosetted foliage in *Baeckea preissiana*, Bell Track South



Fig. 3.7 Elongate shoot growth in *Dryandra cirsioides*, Bell Track North

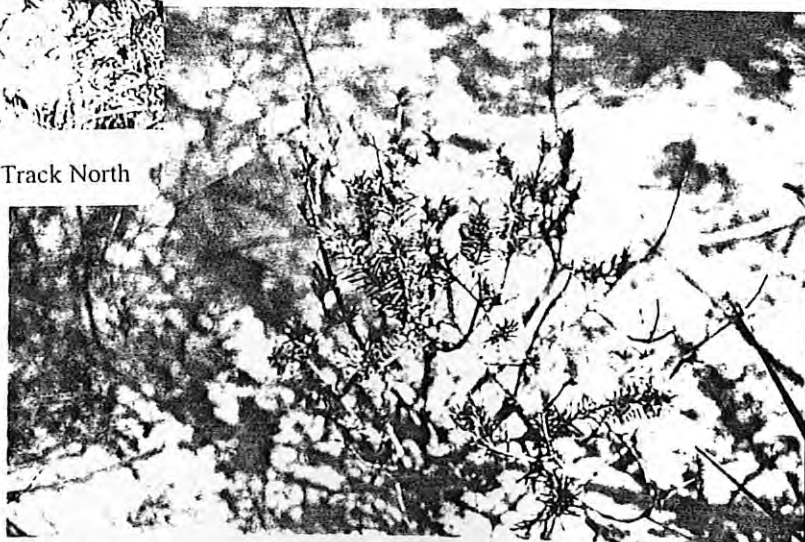


Fig. 3.8 Chlorotic new growth in *Petrophile phyllicoides*, Bell Track South

of this was of normal appearance while some had small leaves and a spindly appearance.

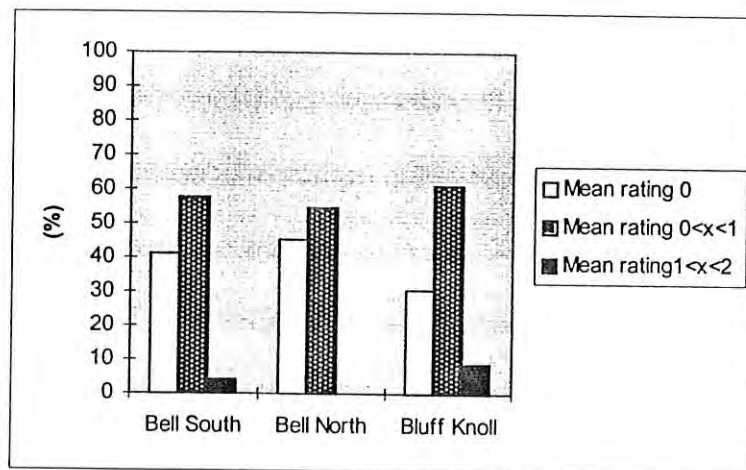


Fig. 3.9. Percentage of species at Bell Track South, Bell Track North and Bluff Knoll with mean phytotoxicity ratings in categories 0; $0 < x \leq 1$; $1 < x \leq 2$. Data is the mean of four assessments, May 1997-November 1998.

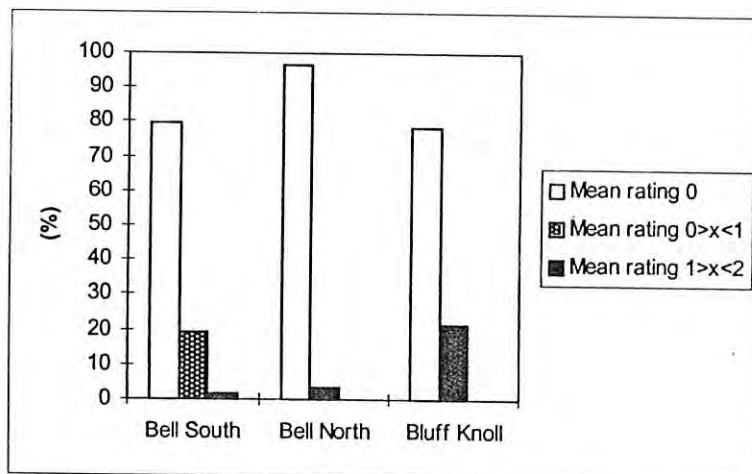


Fig. 3.10. Percentage of species at Bell Track South, Bell Track North and Bluff Knoll with mean phytotoxicity ratings at the final assessment 17 months post-spray in categories 0; $0 < x \leq 1$; $1 < x \leq 2$.

Bell Track North

Of the 55 species assessed at the Bell North site, 47.3% of species had no symptoms. Averaged over the whole assessment period, 52.7% had mild phytotoxicity symptoms (mean ratings $>0, \leq 1$) (Fig 3.9). At the last assessment 96.4 % of species had no symptoms (Fig.3.10). Severe phytotoxicity (mean rating $>3, \leq 4$) was observed in mallee *Eucalyptus* species outside assessment quadrats, these species demonstrated good recovery by the final assessment.

Growth abnormalities were apparent in 7.3% of species (Table 3.5). Chlorosis was evident in one species, *Leucopogon conostephoides*. At the last assessment growth abnormalities persisted in two Myrtaceous species.

Bluff Knoll

Of 23 species assessed for phytotoxicity symptoms at the Bluff Knoll site, 30.5% had no symptoms. Averaged over the assessment period, 60.9% had mild symptoms (mean ratings $>0, \leq 1$) and 9% of species had moderate symptoms (mean ratings $>1, <2$) (Fig.3.9). By the final assessment 78% of species had no symptoms (Fig 3.10).

Foliar chlorosis was observed in 13% of species and a reduction in leaf size of new growth in 8.7% of species (Table 3.5). At the time of the last assessment no growth abnormalities were apparent but foliar chlorosis persisted in *K. montana*.

Table 3.5 Numbers of species at each study site showing growth abnormalities or chlorosis during the study period and at the final assessment. Percentage of species affected given in parenthesis.

	No. of species assessed	Assessments 1-4		Assessment 4	
		Growth abnormalities	Chlorosis	Growth abnormalities	Chlorosis
Bell Track South	68	11 (16.2)	6 (8.8)	7 (10.3)	2 (2.9)
Bell Track North	55	4 (7.3)	1 (1.8)	2 (3.6)	0 (0)
Bluff Knoll	23	2 (8.7)	3 (13)	0 (0)	1 (4.3)

***Eucalyptus* phytotoxicity**

At the Bell Track North site, phosphite application resulted in severe to extreme phytotoxicity in several eucalypt species including *E. redunca*. By two weeks post spray, phytotoxicity was expressed as patchy to complete foliar necrosis of mature leaves and tip necrosis of emerging leaves. Necrosis of stem tissue was also observed as well as necrosis and discoloration of flower buds. Widespread release of seed from fruit capsules also occurred. Severe phytotoxicity ratings continued in spring 1997 (Table 3.6) although epicormic resprouting had commenced. By March 1998, plant health had improved considerably and recovery was almost complete by November 1998 (Table 3.6). Defoliation persisted only where necrosis of stem tissue had taken place.

Table 3.6. Mean phytotoxicity rating of *Eucalyptus redunca* from two weeks to 17 months after phosphite application at 24kg ha⁻¹. Values are the mean of 15 individuals.

<i>Eucalyptus redunca</i>	May 1997	October 1997	March 1998	November 1998
Mean Phytotoxicity rating	4.2	3.9	2.8	1.1

Plant growth

Height increments in sprayed seedlings of *K. montana* on Bluff Knoll at 17 months post-spray were slightly less than those of unsprayed seedlings, however, differences were not significant ($p > 0.05$) (Table 3.7).

Table 3.7. Mean height increment in *Kunzea montana* seedlings 17 months after phosphite application at 24kg ha⁻¹. Values are the mean of 15 individuals $\pm$ standard error.

Phosphite application	Mean height increment $\pm$ standard error (cm)
24kg ha ⁻¹	2.9 $\pm$ 0.5
Unsprayed	3.2 $\pm$ 0.7

Plant Reproduction

Flower production in *Baeckea preissiana* and *Calytrix leschenaultia* in spring 1997, five months after phosphite application was significantly ($p < 0.01$) lower in

sprayed compared with unsprayed plants (Table 3.8). In *B. preissiana* an abundance of immature flower buds was observed in sprayed plants while tip defoliation occurred in both species, in particular, in *C. leschenaultia*.

The following spring, flower production continued lower in sprayed plants compared with controls but differences were not statistically significant ($p>0.05$).

Table 3.9. Mean flower production in *Baeckea preissiana* and *Calytrix leschenaultia* following phosphite application at 24kg ha⁻¹ in autumn 1997. Values are the mean of 18 plants $\pm$ standard error.

	October 1997		November 1998	
	Control	Sprayed	Control	Sprayed
<i>Baeckea preissiana</i>	90.8 $\pm$ 13.9	4.4 $\pm$ 2.1	36.7 $\pm$ 5.3	27.7 $\pm$ 4
<i>Calytrix leschenaultia</i>	19.8 $\pm$ 6.4	0.6 $\pm$ 0.4	28.7 $\pm$ 12.1	8.7 $\pm$ 4.3

4. DISCUSSION

At Bell Track South, phosphite was effective in controlling the spread of *P. cinnamomi* to disease free vegetation two years after phosphite application in autumn 1997. There was considerable evidence of disease activity, manifested by recent plant deaths along the non-sprayed disease front, in March 1998, November 1998 and in April 1999 following a wet winter. Susceptible species on the sprayed dieback front had therefore been clearly challenged by the fungus. Percentage survival of *L. inermis*

and *B. baxteri* in sprayed quadrats declined from November 1998 to April 1999 which may indicate the onset of reduced disease control at two years post spray. In contrast observation of other dieback-fronts within the sprayed area revealed minimal disease activity or plant deaths at this time. The monitoring quadrats were situated in an area of high water run-off paralleled by high plant growth rates which suggest that faster dilution of phosphite within these plants compared with the other sites may be associated with reduced disease control (Komorek and Shearer 1998). Further monitoring is necessary to ascertain how long this control will last for and whether control will persist beyond the time when detectable levels of phosphite remain in plant tissue. Recent observations of other spray sites on the South Coast indicate that a loss of disease control occurs at 24 to 34 months after phosphite application at 24 or 48kg ha⁻¹ (S. Barrett, M. Grant pers comm).

There was only a low level of disease activity in both sprayed and non-sprayed dieback-infected vegetation. This suggests that low levels of inoculum remained after the wave of disease activity had moved through due to the significant loss of *Phytophthora* -susceptible species. Longer term monitoring will therefore be necessary to assess whether phosphite can assist in the rehabilitation of this dieback-infected vegetation as remaining *Phytophthora*-sensitive species mature or seedlings recruit.

Disease activity was also low on in both the non-sprayed and sprayed, dieback-affected and dieback-free, vegetation on the heavier soils of Bell Track North. Therefore, this site will also require further monitoring to assess the effectiveness of phosphite.

At the Bluff Knoll site percentage survival was significantly higher in *Sphenotoma* and *Andersonia* seedlings in sprayed compared with control quadrats at 18 months and two years post-spray. However, there was still a considerable decline in numbers in the sprayed plots most of which occurred in the first year post-spray and percentage survival of the species assessed were lower than at Bell Track South. This suggests that numbers of seedlings were already infected at the time of spraying but failed to show symptoms of infection. It is also possible that some of the plant deaths observed in *Sphenotoma* were related to naturally thinning of dense seedling populations. There were no plant deaths from November 1998 to April 1999 in sprayed quadrats in contrast to the Bell Track South site. This may reflect a greater persistence of phosphite or its by-product following initial high phosphite uptake in these slow growing seedlings. Similarly, little disease activity was apparent at two years post spray at Isongerup Peak in the eastern Stirling Range (M. Grant, S. Barrett pers. comm.). In contrast, considerable disease activity following summer rainfall was apparent at two years post spray at Mt Success in the eastern Stirling Range (M. Grant, S. Barrett pers. comm.). This site was sprayed in 1997 at the same time and rate as Bluff Knoll. The plant community at Mt Success occurs at a lower altitude than the Bluff Knoll or Isongerup community and showed higher growth rates which may have resulted in greater dilution of the chemical. This community has also retained a substantially greater proportion of proteaceous species in which phosphite uptake and disease control may have been less effective.

The relatively low levels of phosphite recorded for the proteaceous species *Lambertia* and *Dryandra* compared with *Sphenotoma* (Epacridaceae) seedlings, may

relate to individual species traits such as leaf characteristics, or differences in community canopy cover which may influence phosphite uptake.

Phosphite concentrations also declined faster in the proteaceous species compared with the epacrid, *Sphenotoma*. This may reflect faster dilution of the chemical in these large shrub species which have faster growth rates compared with the relatively slow growth of *Sphenotoma* situated in the more extreme environment encountered on the Bluff Knoll summit. Alternatively species may vary in their ability to metabolise or eliminate the chemical. As phosphite levels in *L. inermis* and *D. cirsioides* had dropped almost four-fold by five months post spray it is likely that phosphite concentrations were negligible by the last assessment at 17 months post-spray. Greater concentrations of phosphite recorded in *L. inermis* roots compared with shoots at ten months post spray suggests that concentrations may have remained sufficiently high in root tissue to provide continued disease control. Alternatively, it is possible that phosphite was converted into another active agent which provided control of *P. cinnamomi*.

In planta phosphite concentrations in unwashed samples of *L. inermis* and *D. cirsioides* from trial sprays were considerably higher than concentrations in washed samples from the operational sprays. This indicates that in these Proteaceous species a large proportion of the chemical was not taken up from leaf surfaces. As uptake of available active ingredient appears to be poor in the Proteaceae it is possible that an alternative surfactant to Synertrrol may enhance foliar uptake in this family. Greater uptake may in turn reduced the output of chemical required. There was less difference in concentrations between washed and unwashed samples of *Sphenotoma* sp. Stirling

Range. This may reflect more efficient uptake in this species or the moister environment of this site which effectively washed the leaves.

Although the plant species assessed demonstrated a range of phytotoxicity responses to phosphite application, at the application rate used the majority of species had minimal symptoms. Plant health may be compromised at application rates greater than 24 kg ha⁻¹. Greater sensitivity to phosphite (mild to moderately severe symptoms) was apparent in members of the families Myrtaceae, Epacridaceae and Proteaceae. Severe foliar necrosis occurred in eucalypt species but full recovery was evident by the final assessment, 17 months later.

Although many species recovered well from foliar necrosis, growth abnormalities such as small deformed foliage and chlorosis persisted in particular species. Growth abnormalities were most apparent in the Proteaceae followed by the Myrtaceae and were more frequent at the Bell Track South site. This difference between sites may reflect some effect of the lower nutrient status of the sandy soils of Bell Track south. Similar growth abnormalities similar to zinc deficiency symptoms have been reported in maize seedlings following soil drenching with phosphite (Seymour *et al.* 1994). Observations of growth abnormalities in Proteaceous species after phosphite application in other plant communities indicates that healthy new shoots ultimately replace abnormal foliage (Barrett PhD in prep.).

Phosphite application in autumn was associated with reduced flowering the following spring in the two species (*C. leschenaultii* and *B. preissiana*) assessed at Bell Track South. The individuals assessed occurred within dieback infected vegetation with a very open canopy cover and consequently intercepted a relatively

higher proportion of the spray application. Tip defoliation may reduce bud set and flowering in species such as *C. leschenaultii* and *B. preissiana*, which produce flowers on new terminal growth. However, the abundance of immature flower buds in *B. preissiana* suggests that phosphite may exert a hormonal or nutritional influence also. The abnormal presence of immature flower buds has previously been related to symptoms of zinc deficiency associated with imbalance of the hormone auxin (Mengel and Kirkby 1987). Potential short-term effects on plant reproduction as a result of reduced flower production in the reproductive season post spray in particular phosphite-sensitive species should be taken into consideration when selecting application rates and times, particularly where there are concerns about the seed banks of target species.

Monitoring of plant height in *K. montana* seedlings on Bluff Knoll did not show any significant effect on plant growth.

Any short term negative effects of phosphite on plant health must be balanced by consideration of the far greater impact of *Phytophthora* on plant species survival and community structure, community ecology (Wills and Keighery 1994) and effects on fauna (Wilson *et al* 1990; 1994). With the exception of the Bell Track site, the sites targeted for phosphite application in the South Coast Region all contain 'Threatened Species' several of which are 'Critically Endangered' (Dept. of Conservation and Land Management 1994) as a direct result of *P. cinnamomi*. Recent phosphite applications in the Eastern Stirling Community have utilised a reduced application rate of 12 kg ha⁻¹ in light of the reduced canopy cover of post-fire regenerating vegetation and the critically endangered status of many species. The duration of control at this rate is unknown and will require careful monitoring.

These target sites, with the exception of the Bell Track site, are also of limited extent (in the order of tens of hectares) and therefore phosphite is being applied to relatively small area. The value in spraying the Bell Track site lies in unique status of the Fitzgerald River National Park which is free of *Phytophthora cinnamomi* with the exception of the Bell Track infection. In contrast 60% of the Stirling Range National Park is infected by *P. cinnamomi*. Phosphite application at the Bell Track is critical to ensure the area of infection is contained.

5. RECOMMENDATIONS

1. Continue to monitor species survival in sprayed and control plots at six-monthly intervals
2. Re-spray the Bell Track and Bluff Knoll Site autumn 2000 maintaining the control quadrats for ongoing monitoring.
3. Use survivorship monitoring data available from this project and from other phosphite applications to develop appropriate spraying regimes taking into account community structure, target species and plant growth rates
4. Investigate the potential of other surfactants/ adjuvants to enhance phosphite uptake in Proteaceous species

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**APPENDIX 1. MEAN PHYTOTOXICITY RATINGS OF SPECIES ASSESSED
AT BELL TRACK SOUTH (1a), BELL TRACK NORTH (1b) AND BLUFF
KNOLL(1c) FOLLOWING PHOSPHITE APPLICATION AT 24 KG HA⁻¹**

Appendix 1a

Bell Track South

	Date of assessment				Mean rating
	May-97	Oct-97	Mar-98	Nov-98	
<i>Stirlingia tenuifolia</i> var. <i>tenuifolia</i>	2.00	3.00	0.50	0.00	1.50
<i>Lysinema obovatum</i>	0.25	2.25	2.00	1.00	1.38
<i>Baeckea preissiana</i>	1.25	1.25	1.50	0.75	1.19
<i>Agonis spathulata</i>	2.50	1.25	0.25	0.00	1.00
<i>Isopogon polycephalus</i>	1.00	1.00	1.00	0.50	0.90
<i>Leucopogon conostephioides</i>	1.25	1.00	0.75	0.25	0.81
<i>Calytrix leschenaultii</i>	2.00	1.00	0.00	0.00	0.75
<i>Daviesia reversifolia</i>	1.00	2.00	0.00	0.00	0.75
<i>Dryandra cuneata</i>	1.00	1.25	0.25	0.25	0.69
<i>Petrophile longifolia</i>	0.50	1.25	0.50	0.50	0.69
<i>Petrophile phyllioides</i>	1.00	0.25	0.75	0.75	0.69
<i>Andersonia aff simplex</i>	0.00	1.25	1.50	0.00	0.67
<i>Beaufortia empetrifolia</i>	2.00	0.67	0.00	0.00	0.67
<i>Isopogon trilobus</i>	0.00	0.00	1.25	1.25	0.63
<i>Monotoca oligarrhenoides</i>	0.00	1.50	1.00	0.00	0.63
<i>Oligarrhena micrantha</i>	0.50	1.00	1.00	0.00	0.63
<i>Conospermum distichum</i>	1.00	0.33	0.67	0.33	0.58
<i>Banksia baxteri</i>	0.00	0.00	1.25	1.00	0.56
<i>Dasypogon bromeliifolius</i>	1.00	1.00	0.00	0.00	0.50
<i>Petrophile teretifolia</i>	0.25	0.25	0.75	0.50	0.44
<i>Melaleuca striata</i>	1.25	0.25	0.00	0.00	0.38
<i>Chamelaucium megalopetalum</i>	0.33	0.33	0.33	0.33	0.33
<i>Dryandra brownii</i>	0.25	0.50	0.25	0.25	0.31
<i>Allocasuarina thuyoides</i>	1.00	0.00	0.00	0.00	0.25
<i>Calectasia cyanea</i>	1.00	0.00	0.00	0.00	0.25
<i>Hakea obliqua</i>	1.00	0.00	0.00	0.00	0.25
<i>Verticordia plumosa</i>	1.00	0.00	0.00	0.00	0.25
<i>Anarthria prolifera</i>	0.00	0.50	0.25	0.00	0.19
<i>Hibbertia recurvifolia</i>	0.00	0.25	0.50	0.00	0.19
<i>Leucopogon minutifolius</i>	0.00	0.50	0.25	0.00	0.19
<i>Caustis dioica</i>	0.67	0.00	0.00	0.00	0.17
<i>Gompholobium scabrum</i>	0.00	0.33	0.33	0.00	0.17
<i>Melaleuca scabra</i>	0.67	0.00	0.00	0.00	0.17
<i>Banksia nutans</i> var. <i>nutans</i>	0.00	0.00	0.50	0.00	0.13
<i>Conospermum teretifolium</i>	0.50	0.00	0.00	0.00	0.13
<i>Dampiera linearis</i>	0.00	0.00	0.33	0.00	0.13
<i>Lambertia inermis</i>	0.00	0.25	0.00	0.25	0.13
<i>Stylidium repens</i> var. <i>repens</i>	0.33	0.00	0.00	0.00	0.08
<i>Amphipogon turbinatus</i>	0.25	0.00	0.00	0.00	0.06
<i>Anarthria scabra</i>	0.00	0.25	0.00	0.00	0.06
<i>Conostylis vaginata</i>	0.00	0.25	0.00	0.00	0.06
<i>Conothamnus aureus</i>	0.00	0.25	0.00	0.00	0.06
<i>Adenanthos cuneatus</i>	0.00	0.00	0.00	0.00	0.00

<i>Banksia coccinea</i>	0.00	0.00	0.00	0.00	0.00
<i>Boronia spathulata</i>	0.00	0.00	0.00	0.00	0.00
<i>Calothamnus gracilis</i>	0.00	1.00	0.00	0.00	0.00
<i>Cassytha racemosa</i>	0.00	0.00	0.00	0.00	0.00
<i>Darwinia diosmoides</i>	0.00	0.00	0.00	0.00	0.00
<i>Darwinia</i> sp. (SB 712)	0.00	0.00	0.00	0.00	0.00
<i>Drosera scorpioides</i>	0.00	0.00	0.00	0.00	0.00
<i>Franklandia fucifolia</i>	0.00	0.00	0.00	0.00	0.00
<i>Hakea victoria</i>	0.00	0.00	0.00	0.00	0.00
<i>Hibbertia lineata</i>	0.00	0.00	0.00	0.00	0.00
<i>Jacksonia lehmannii</i>	0.00	0.00	0.00	0.00	0.00
<i>Laxmannia brachyphylla</i>	0.00	0.00	0.00	0.00	0.00
<i>Laxmannia sessiliflora</i>	0.00	0.00	0.00	0.00	0.00
<i>Lomandra nigricans</i>	0.00	0.00	0.00	0.00	0.00
<i>Desmocladius flexuosus</i>	0.00	0.00	0.00	0.00	0.00
<i>Lyginia barbata</i>	0.00	0.00	0.00	0.00	0.00
<i>Mesomelaena graciliceps</i>	0.00	0.00	0.00	0.00	0.00
<i>Mesomelaena stygia</i>	0.00	0.00	0.00	0.00	0.00
<i>Mesomelaena tetragona</i>	0.00	0.00	0.00	0.00	0.00
<i>Platysace effusa</i>	0.00	0.00	0.00	0.00	0.00
<i>Pultenaea neurocalyx</i>	0.00	0.00	0.00	0.00	0.00
<i>Restio</i> sp. (SB 670)	0.00	0.00	0.00	0.00	0.00
<i>Schoenus</i> aff <i>pleistemoneus</i>	0.00	0.00	0.00	0.00	0.00
<i>Schoenus caespititius</i>	0.00	0.00	0.00	0.00	0.00
<i>Tricostularia neesii</i> var. <i>elatior</i>	0.00	0.00	0.00	0.00	0.00

Appendix 1b

Bell Track North	Date of assessment				Mean rating
	May-97	Oct-97	Mar-98	Nov-98	
<i>Acacia myrtifolia</i>	1.50	1.00	1.50	0.00	1.00
<i>Kunzea preissiana</i>	1.00	0.00	0.00	1.00	1.00
<i>Leptospermum spinescens</i>	2.00	1.00	1.00	0.00	1.00
<i>Eucalyptus micranthera</i>	1.00	1.00	1.00	0.00	0.75
<i>Eucalyptus tetragona</i>	3.00	0.50	0.50	0.00	0.75
<i>Isopogon buxifolius</i>	1.00	0.67	0.67	0.00	0.75
<i>Leptospermum maxwellii</i>	0.50	0.00	0.00	0.00	0.75
<i>Melaleuca pentagona</i> var <i>subulifolia</i>	1.00	0.00	0.00	0.00	0.75
<i>Petrophile divaricata</i>	1.00	0.00	0.00	0.00	0.75
<i>Leucopogon conostephioides</i>	0.75	0.00	0.00	0.00	0.69
<i>Dryandra cirsioides</i>	0.25	1.00	1.00	0.00	0.56
<i>Agonis spathulata</i>	1.00	0.50	0.50	0.00	0.50
<i>Isopogon teretifolius</i>	0.33	0.00	0.00	0.00	0.42
<i>Conostylis setigera</i>	1.00	0.33	0.33	0.00	0.33
<i>Acacia</i> sp. (SB 769)	0.00	0.50	0.50	0.00	0.25
<i>Allocasuarina thuyoides</i>	1.00	0.00	0.00	0.00	0.25
<i>Amphipogon turbinatus</i>	1.00	0.00	0.00	0.00	0.25
<i>Boronia crassifolia</i>	0.50	0.50	0.00	0.00	0.25
<i>Calectasia grandiflora</i>	1.00	0.00	0.00	0.00	0.25
<i>Daviesia teretifolia</i>	0.33	0.33	0.33	0.00	0.25
<i>Hakea varia</i>	1.00	0.00	0.00	0.00	0.25
<i>Synaphea polymorpha</i>	1.00	0.00	0.00	0.00	0.25
<i>Banksia violacea</i>	0.00	0.50	0.25	0.00	0.19
<i>Anarthria humilis</i>	0.67	0.00	0.00	0.00	0.17
<i>Melaleuca pentagona</i> var <i>latifolia</i>	0.67	0.00	0.00	0.00	0.17
<i>Beaufortia micrantha</i> var. <i>micrantha</i>	0.50	0.00	0.00	0.00	0.13
<i>Leucopogon minutifolius</i>	0.50	0.00	0.00	0.00	0.13
<i>Mesomelaena stygia</i> subsp. <i>stygia</i>	0.50	1.00	1.00	0.00	0.13
<i>Dryandra arctotidis</i>	0.33	0.00	0.00	0.00	0.08
<i>Hakea corymbosa</i>	0.00	0.00	0.33	0.00	0.08
<i>Allocasuarina microstachya</i>	0.00	0.00	0.00	0.00	0.00
<i>Calothamnus gracilis</i>	0.00	0.00	0.00	0.00	0.00
<i>Cassytha glabella</i> forma <i>glabella</i>	0.00	0.00	0.00	0.00	0.00
<i>Darwinia</i> sp. (SB 712)	0.00	0.00	0.00	0.00	0.00
<i>Darwinia diosmoides</i>	0.00	0.00	0.00	0.00	0.00
<i>Neurachne alopecuriodea</i>	0.00	0.00	0.00	0.00	0.00
<i>Hakea cygna</i> subsp. <i>cygna</i>	0.00	0.00	0.00	0.00	0.00
<i>Hakea lehmanniana</i>	0.00	0.00	0.00	0.00	0.00

<i>Hakea trifurcata</i>	0.00	0.00	0.00	0.00	0.00
<i>Hibbertia lineata</i>	0.00	0.00	0.00	0.00	0.00
<i>Jacksonia lehmannii</i>	0.00	1.00	1.00	0.00	0.00
<i>Lepidobolus preissianus</i>	0.00	0.00	0.00	0.00	0.00
<i>Lepidosperma viscidum</i>	0.00	0.00	0.00	0.00	0.00
<i>Leucopogon concinnus</i>	0.00	0.00	0.00	0.00	0.00
<i>Leucopogon tamminensis</i>	0.00	0.00	0.00	0.00	0.00
<i>Lysinema ciliatum</i>	0.00	0.00	0.00	0.00	0.00
<i>Melaleuca scabra</i>	0.00	0.00	0.00	0.00	0.00
<i>Nemcia hookeri</i>	0.00	0.00	0.00	0.00	0.00
<i>Persoonia striata</i>	0.00	0.00	0.00	0.00	0.00
<i>Schoenus pleiostemoneus</i>	0.00	0.00	0.00	0.00	0.00
<i>Schoenus minutulus</i>	0.00	0.00	0.00	0.00	0.00
<i>Spyridium oligocephalum</i>	0.00	0.00	0.00	0.00	0.00
<i>Tricostularia neesii</i> var. <i>neesii</i>	0.00	0.00	0.00	0.00	0.00
<i>Verticordia chrysantha</i>	0.00	0.00	0.00	0.00	0.00
<i>Verticordia plumosa</i>	0.00	0.00	0.00	0.00	0.00

Appendix 1c

Bluff Knoll	Date of assessment				Mean rating
	May-97	Oct-97	Mar-98	Nov-98	
<i>Sphenotoma</i> sp. Stirling Range	1.00	1.33	1.17	1.00	1.13
<i>Andersonia echinocephala</i>	1.00	1.20	1.20	1.00	1.10
<i>Andersonia axilliflora</i>	1.00	1.00	1.00	1.00	1.00
<i>Kunzea montana</i>	0.83	1.00	0.17	0.50	0.63
<i>Agonis floribunda</i>	1.00	1.00	0.20	0.00	0.55
<i>Leucopogon gnaphalioides</i>	0.60	0.60	0.80	0.00	0.50
<i>Monotoca oligarrhenoides</i>	0.50	0.00	0.00	0.00	0.50
<i>Aotus genistoides</i>	0.50	0.50	0.50	0.00	0.38
<i>Darwinia collina</i>	0.50	1.00	0.00	0.00	0.38
<i>Melaleuca thymoides</i>	0.75	0.67	0.25	0.25	0.33
<i>Beaufortia anisandra</i>	0.83	0.17	0.17	0.00	0.29
<i>Calothamnus crassus</i>	0.50	0.33	0.00	0.00	0.29
<i>Lysinema fimbriatum</i>	0.00	0.50	0.00	0.00	0.19
<i>Boronia spathulata</i>	0.60	0.00	0.00	0.00	0.15
<i>Desmocladius flexuosus</i>	0.50	0.00	0.00	0.00	0.13
<i>Tetraria capillaris</i>	0.17	0.00	0.00	0.00	0.04
<i>Actinotus rhomboideus</i>	0.00	0.00	0.00	0.00	0.00
<i>Cassytha glabella</i>	0.00	0.00	0.00	0.00	0.00
<i>Dampiera linearis</i>	0.00	0.00	0.00	0.00	0.00
<i>Drosera huegelii</i>	0.00	0.00	0.00	0.00	0.00
<i>Lepidosperma</i> sp. Stirling Range (SB 42)	0.00	0.00	0.00	0.00	0.00
<i>Schoenus efoliatus</i>	0.00	0.00	0.00	0.00	0.00
<i>Xanthosia rotundifolia</i> var <i>rotundifolia</i>	0.00	0.00	0.00	0.00	0.00