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A review of the catchment approach techniques used to manage a *Phytophthora cinnamomi* infestation of native plant communities of the Fitzgerald River National Park on the south coast of Western Australia†

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Abstract

The Fitzgerald River National Park (FRNP) is an International Biosphere Reserve on the south coast of Western Australia. The National Park is recognised for its high biodiversity with over 2000 plant species (including many endemics), threatened ecological communities and rare fauna. In contrast with many other areas of high biodiversity value in the region, the FRNP remains largely free of the introduced plant pathogen, *Phytophthora cinnamomi* Rands, with less than 0.1% of the Park currently infested.

Phytophthora cinnamomi was introduced to the FRNP in 1971 with the construction of the unauthorised Bell Track. Currently, the pathogen is located within an internally draining catchment giving some opportunity for limiting its spread into the rest of the FRNP. In recognition of this, a multi-disciplinary integrated management plan has been implemented to contain *P. cinnamomi* within the current infested catchment. The management plan aimed to accurately identify the area infested with the pathogen, contain it within the current catchment boundaries and reduce the impact on the native plant communities within the infested area. Containment of *P. cinnamomi* within the current catchment protects tens of thousands of hectares of healthy heathland within the Park from the impact of the pathogen.

This review summarises a range of management techniques that have been used to contain the infestation. These techniques include: delimitation with remote sensing technologies; construction of hydrological engineering controls for management of overland flow; installation of vehicle-wash facilities; installation of an animal exclusion perimeter fence and animal control within the fenced area; implementation of strict hygiene and access protocols; installation of root impervious membranes; the application of fungicides and fumigants; rehabilitation of the infested area; and controlled wildfire management.

Keywords: adaptive management; Bell Track, Digital Multi-Spectral Imagery; Phytophthora dieback; policy; procedures.

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Introduction

The South-West Botanical Province of Western Australia (WA) has been recognised as an international biodiversity hotspot (Myers et al., 2000). The impact of the introduced plant pathogen, *Phytophthora cinnamomi* Rands is a major threat to the native plant communities within the province (Shearer et al., 2007). Of the 5710 described plant species in the South-West Botanical Province, Shearer, Crane & Cochrane (2004) estimated that 2284 species are susceptible to *P. cinnamomi* and 800 of these are highly susceptible to the pathogen. When *P. cinnamomi* spreads through bushland, it kills many susceptible plants, resulting in a permanent decline in the structure, function and biodiversity of the whole ecosystem (Shearer et al., 2007; 2009). Changes in composition of the bushland with decline in susceptible shrubs and increases in the number and proportion of resistant grasses and sedges have been reported following infestation (Wills & Keighery, 1994). In addition, native animals that rely on susceptible plants for survival are reduced in numbers or are eliminated from infested sites (Garkaklis et al., 2004).

The Fitzgerald River National Park (FRNP) on the south coast of WA is within the South-West Botanical Province and is designated as an International Biosphere Reserve (Moore et al., 1991; Hopper & Gioia, 2004). Over 2000 species and subspecies of native flowering plants are found in the Park, representing nearly 20% of the total number of plant species in WA (Aplin & Newbey, 1990; Department of Environment and Conservation (DEC), 2009). The FRNP contains over 62 endemic plant species with a further 48 plant species more or less confined to the Park (DEC, 2009). This diverse flora supports a number of threatened animals including the critically endangered western ground parrot (*Pezoporus flaviventris* North) and the endangered dibbler (*Parantechinus apicalis* Gray). There are 17 threatened flora species and 6 threatened fauna species within the FRNP (Chapman & Newby, 1995).

Although *Phytophthora cinnamomi* is widespread across the south coast of WA, the FRNP has remained largely free of the pathogen. This is mostly due to the implementation and consequent success of a number of *Phytophthora* management protocols, including restricting access to the wilderness zone in the centre of the Park. *Phytophthora cinnamomi* was introduced near the wilderness zone of the Park in 1971 during the construction of an unauthorised access track that has become known as the Bell Track (Figure 1). The area infested by the pathogen has expanded over subsequent years to now occupy 212 ha of the Park. This infestation equates to less than 0.1% of the 330 000 ha total area of the Park. This is contrasted by the nearby Le Grand and Stirling Range National Parks that are considered to be over 60 – 80% infested by the pathogen (DEC, 2006).

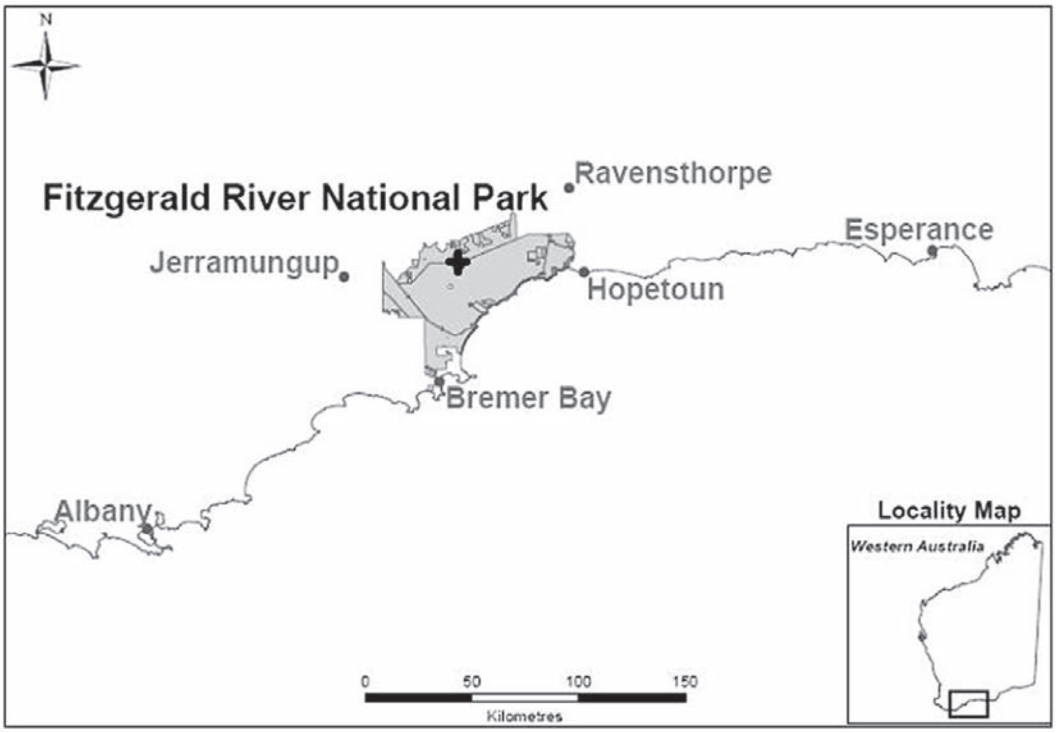

FIGURE 1: The Fitzgerald River National Park is located on the South Coast region of Western Australia halfway between Albany and Esperance. The location of the *Phytophthora cinnamomi* infestation at Bell Track within the National Park is shown (+).

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Two distinct native plant communities and soil types occur across the infested area at Bell Track. The northern half consists of a typical Kwongan heath (Pate & Beard, 1984) with a mosaic of shrublands and mallee-heath. The vegetation type has the mallee shrub *Eucalyptus pleurocarpa* Schauer over a lower storey dominated by *Banksia cirsioides* Meisn., *Banksia violacea* C.A.Gardner, *Beaufortia micrantha* Schauer and *Hakea corymbosa* R.Br. The soil type within this northern area is the Jerramungup system described by Beard (1981) that consists of a shallow grey loam with rock fragments. The disease expression of the pathogen within this area is scattered with deaths in a number of plant species without distinct structural changes at the disease front. The southern half of the infested area is proteaceous heath dominated by *Lambertia inermis* R.Br., *Banksia baxteri* R.Br. and *Banksia coccinea* R.Br. The soil type within the southern area is the Hamersley system described by Beard (1981) that consists of duplex with an A horizon of deep grey sand over a B horizon of yellow sand. Disease expression is highly destructive with the death of the majority of the overstorey species that are important structural species leading to highly defined distinct disease fronts. The difference in impact between the northern and southern sections of the infestation can be attributed to differences in soil type, soil profile and the dominance of highly susceptible overstorey species in the southern area.

In 2006, the pathogen was located within an internally drained catchment on the watershed between two major drainage systems, the Susetta River and Copper Mine Creek. If *Phytophthora cinnamomi* were to enter either of these drainage systems, large areas of the Park would inevitably become infested with this pathogen. In response to this threat the Western Australian Government's Department of Environment and Conservation (DEC) has implemented a large scale containment strategy for the Bell Track infestation through the "Last Stand at Bell Track" project.

Project Planning

In 2004, a Response Plan to the Bell Track infestation was prepared to evaluate management strategies that could be employed to manage the pathogen. Prior to this, the infestation had been managed only through hygiene protocols, access controls and aerial phosphite treatment. In 2006, the State Government of WA allocated funds to attempt to contain the pathogen within its current catchment and the "Last Stand at Bell Track" project commenced. The goal of the project was to contain the pathogen within the current catchment and thereby prevent outbreaks that would threaten the largely disease free status of the Park. The project has four distinct programs: (1) describe and monitor pathogen occurrence; (2) contain the pathogen within the current catchment; (3) reduce the impacts of the pathogen within the infested area; and (4) undertake significant science-based investigations to inform management decisions.

A steering committee was created to oversee the progress of the project and to provide technical input as required. The steering committee was comprised of regional and district staff, nature conservation staff, scientists and senior managers. Subsequently, a project officer was employed to help implement the range of different management initiatives and run the project on a day-to-day basis.

Risk Assessment

To assess the risks associated with the project, a Bayesian Belief Network (BBN) model was developed for the range of management strategies and their effect on containment of the *Phytophthora cinnamomi* infestation (Figure 2). A BBN model is a probabilistic graphical model that represents a set of random variables and their conditional interdependencies and allows complex causal chains linking actions to outcomes to be factored into an articulated series of conditional relationships (Borsuk et al., 2004). We used the BBN to analyse the probabilities of success of different management strategies because it has the capacity to incorporate empirical observations, system sub-models, and expert opinion. The basis in Bayesian inference also means BBNs can be readily updated as new information becomes available (Hart et al., 2005). This information may be derived from research, monitoring and advances in technology and management (Marcot et al., 2006). This would result in expert probability opinions being refined by information and in turn assist decision makers to manage accordingly.

The BBN model developed in the current project aimed to describe the 'cause and effect' relationships between the different management strategies and identified threats that could lead to goal failure. The goal of the current project is to contain the existing infestation within the bounds of the catchment over the next 50 years. The identified risks to goal failure included the threat of:

- hydrological catchment discharge into adjacent catchments;
- animal and human transport of *Phytophthora cinnamomi*; and
- root to root or autonomous spread of the pathogen.

Hydrological catchment discharge into adjacent catchments may be exacerbated by episodic events including high intensity summer rainfall and flooding;

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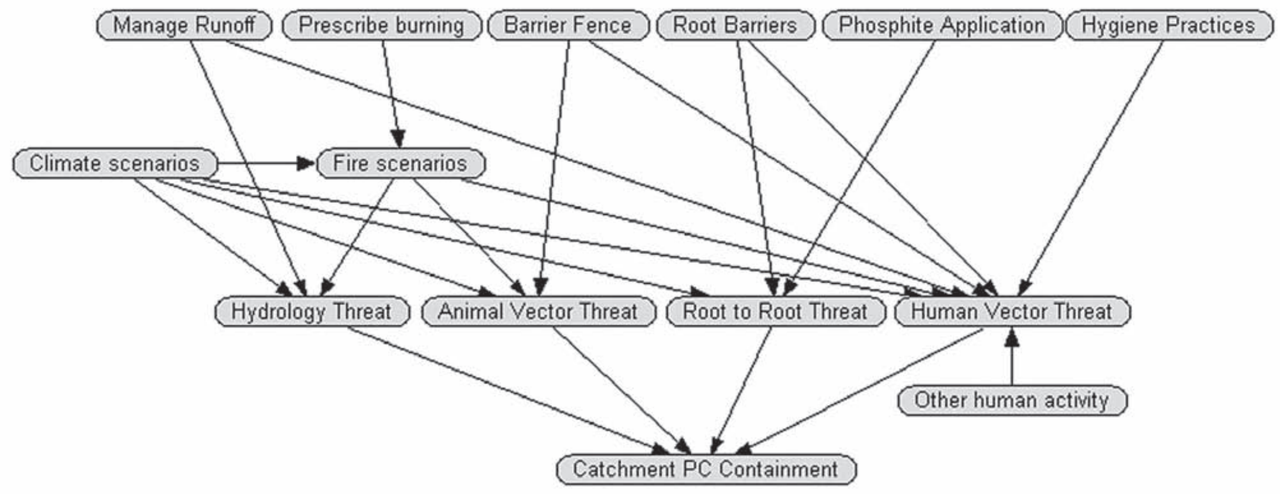

FIGURE 2: The Bayesian Belief Network model was used to elucidate interactions between the different management strategies, identified threats to the project goal and contributing factors. All models presented in this report were generated using Netica software (Norsys, 1997).

and wildfire increasing the risk of increased run-off under episodic rainfall events. The BBN identified that the most effective options in achieving the project's goal are continuing hygiene practices to reduce the human vector threat and ongoing phosphite application to reduce root to root spread (Figures 3 & 4). This scenario (based on hygiene and phosphite) reduced the estimated risk from 67.5% of goal failure if no management applied to a 37% risk of goal failure. Humans provide the greatest threat of goal failure through accidental spread of *Phytophthora cinnamomi*, even with hygiene practices, when undertaking any activity within the Bell Track catchment. Prescribed burning is important to maintain the integrity of vegetation. This approach reduced the risk of uncontrolled burning to less than 60% of the catchment which subsequently reduces the risk of a high rainfall triggered flood event causing *P. cinnamomi* to wash out of the catchment.

Programme 1: Determine and monitor the occurrence of the pathogen

Project planning required an accurate map of the occurrence of *Phytophthora cinnamomi* so 1 : 4500-scale aerial photographs were captured. These photographs were visually assessed by the DEC's *Phytophthora* disease interpreters to identify the likely infestation boundary. The accuracy of the photographs was checked on-the-ground using visual inspection by individuals with a hand held Global Positioning System (GPS) unit. The occurrence of the pathogen was determined by mapping disease expression, including chlorosis or death of indicator species and structural changes in the vegetation community, in 2007 and again in 2009 (Figure 5). The boundary of the disease centre was diffuse in the northern area and discrete in the proteaceous heath in the southern area. The mapped occurrence was confirmed by a systematic process of collecting soil and tissue samples for field detection of the pathogen.

During the four years of monitoring (2006 to 2009), the disease centre expanded from 142.9 ha to 212.8 ha. Within infested sites in south-west WA autonomous spread of the pathogen can result from surface or subsurface water flows, and root to root transmission of the pathogen (Shearer & Tippett, 1989). Large rain events can result in overland flow leading to rapid disease centre expansion, while root to root transmission of the pathogen can result in an average of 1 – 3 m expansion per year (Dunstan et al., 2008). There were a number of significant rainfall events in 2006 and 2007 at Bell Track that are likely to have contributed to this significant expansion of the disease centre. For example, 113 mm of rainfall over 24 hrs (Bureau of Meteorology, Ravensthorpe weather station) is considered to have resulted in a 500 m extension in the south-east of the catchment. This rapid extension in the disease centre was observed by the mass collapse of the *Banksia baxteri* along a 500 m drainage line within weeks of the rain event. It is essential that, to contain the pathogen at Bell Track, any management strategy needs to address yearly incremental expansion through root to root transmission as well as extreme episodic rainfall events.

In addition to aerial photographs, digital multi-spectral imagery (DMSI) was used to determine disease occurrence and monitor disease centre expansion. Digital multi-spectral imagery systems are well-established, low-cost tools for collection of remotely sensed digital imagery for land use management

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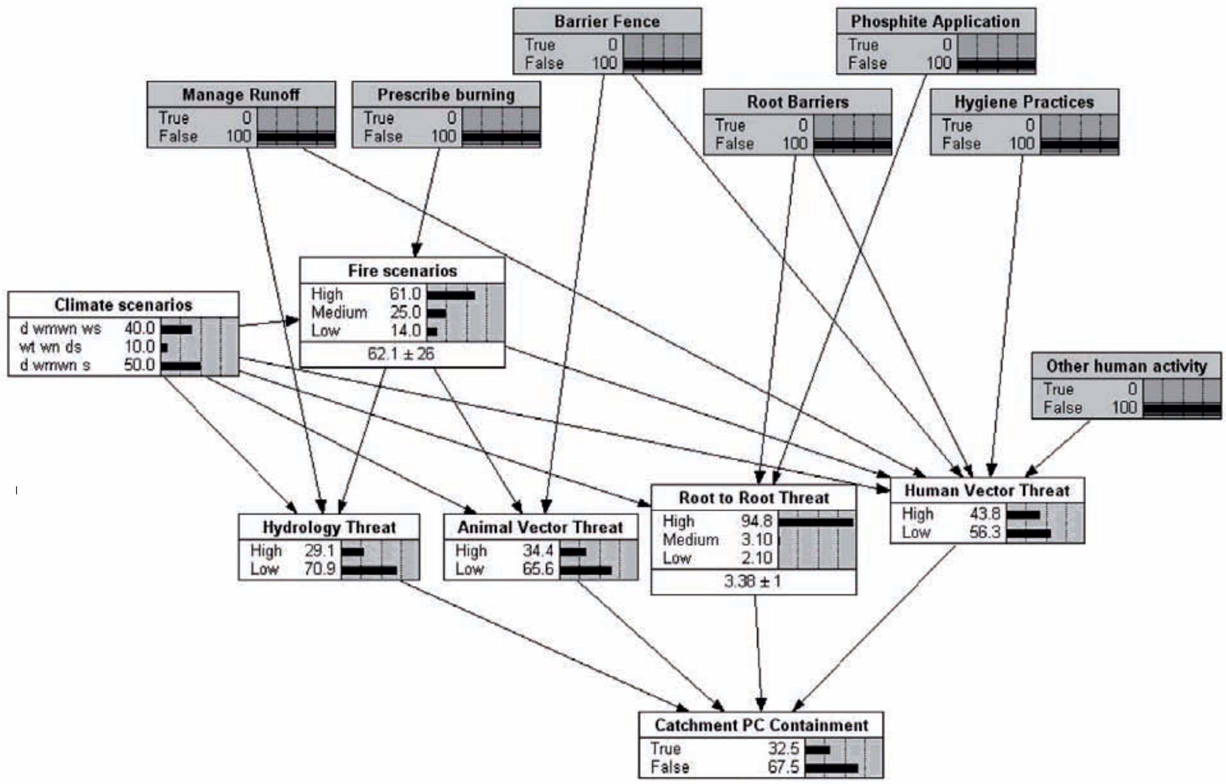

FIGURE 3: The Bayesian Belief Network model based on the 'do nothing' scenario gives a 32.5% chance of *Phytophthora cinnamomi* being contained within the catchment after 50 years. Three different climate scenarios were included in the model: dry warm winter and wet summer (d wmwn ws); wet winter and dry summer (wt wn ds); and dry warm winter and dry summer (d wmwn s).

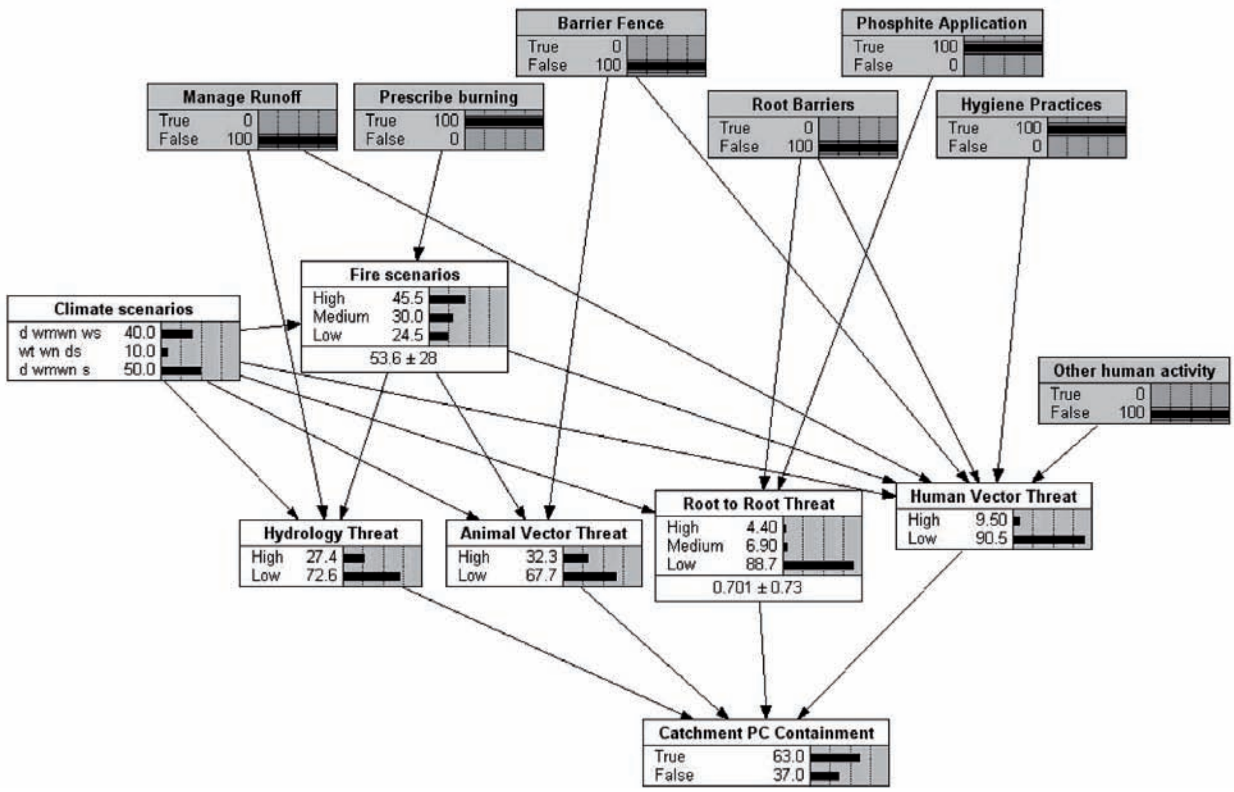

FIGURE 4: The Bayesian Belief Network scenario that gave the highest probability (63%) of pathogen containment included on-going phosphite application and implementation of strict hygiene measures. Three different climate scenarios were included in the model: dry warm winter and wet summer (d wmwn ws); wet winter and dry summer (wt wn ds); and dry warm winter and dry summer (d wmwn s).

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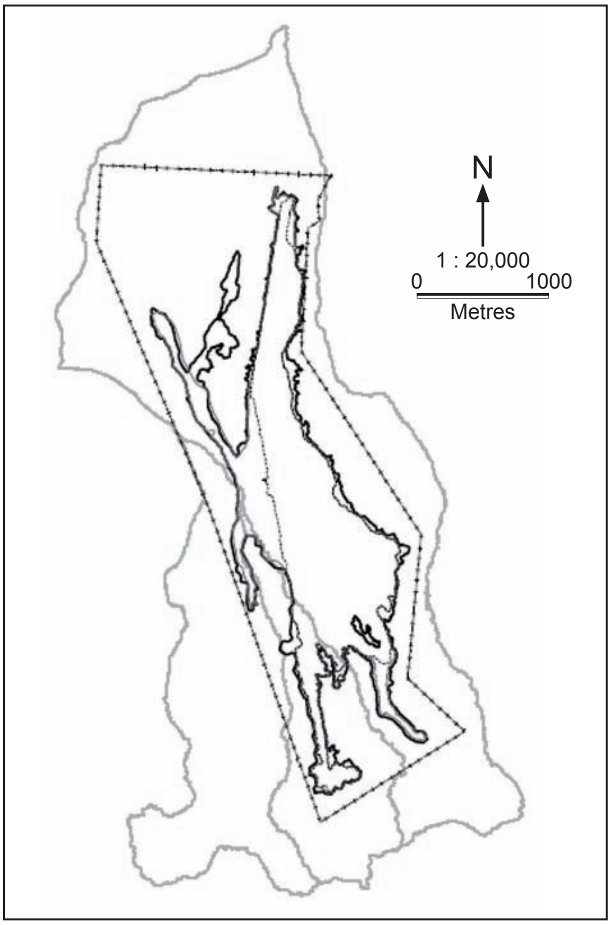

FIGURE 5: The occurrence of *Phytophthora cinnamomi* at the Bell Track infestation in the Fitzgerald River National Park in 2009. The boundary of the infestation at the different times of assessment is shown in black and the sub-catchment boundaries are shown in grey. The checked line shows the position of the fence and fire breaks surrounding the infested area.

and monitoring applications (Goodwin et al., 2005). However, they have only been trialled in a few applications for remote sensing of *P. cinnamomi* occurrence (Hill et al., 2009; Zdunic et al., 2010). SpecTerra Services (Leederville, Western Australia) was contracted to provide image acquisition and processing services for the purposes of determining disease occurrence. The imagery was gathered in four wavebands, 25 nm wide, centred about the principal reflectance features of vegetation in the blue, green, red and near infrared portions of the spectrum. In May 2007 and 2009, DMSI was captured in a 0.4 by 0.4 m cell or pixel size by flying over the Bell Track infestation. The impact of the infestation reduces plant community structure and biomass resulting in a low plant cell density (Figure 6A). By flying the site twice, the change in infestation could be determined. This has proven useful in monitoring both rates of disease centre expansion and efficacy of the different management strategies (Figure 6B).

Over 4000 soil and plant tissue samples were collected over the four years of the project. The diagnostic results (pathogen presence/absence) of these samples were used to confirm the mapping of disease occurrence by disease symptoms or to determine pathogen absence for major earth works including the construction of the fence. The sampling was conducted systematically across the whole catchment focusing on determining the edge of the infested area and confirming pathogen freedom outside the infestation. Samples were tested for the presence of *Phytophthora* species using traditional baiting techniques (Marks & Kassaby, 1974) with *Eucalyptus sieberi* L.A.S. Johnson and *Pimelia ferruginea* Labill. baits. The project also incorporated a number of more innovative techniques such as: identification of *P. cinnamomi* from soil samples using molecular identification (Williams et al., 2009); identification of different *P. cinnamomi* variants using mating and growth rate tests (Old et al., 1984); and the identification of other *Phytophthora* species using sequencing of the internal transcribed spacers (ITS) from the ribosomal DNA (rDNA) (Cooke et al., 2000; White et al., 1990).

Programme 2: Contain the pathogen within the current catchment

Successful containment of the *Phytophthora cinnamomi* infestation within the catchment was dependent on the following strategies:

- preventing root to root transmission of *P. cinnamomi* beyond the infestation boundary;
- preventing discharge of surface water-flow containing the pathogen's zoospores or colonised organic material from the infested catchment;
- preventing discharge of sub-surface water-flow containing zoospores or colonised organic material from the infested catchment;
- controlling animal vectoring;
- controlling human vectoring including during wildfire management; and
- building capacity (skills and knowledge) for planning for and monitoring effectiveness of the strategies in an adaptive management framework.

The primary strategy to control the threat of human vectoring was to implement a strict access and hygiene policy for all visitors to the site including field staff, researchers and contractors. In accordance with the Fitzgerald River National Park management plan (Moore et al., 1991), all vehicle access to the Bell Track infestation within the Wilderness Zone requires approval from the Conservation Commission of WA.

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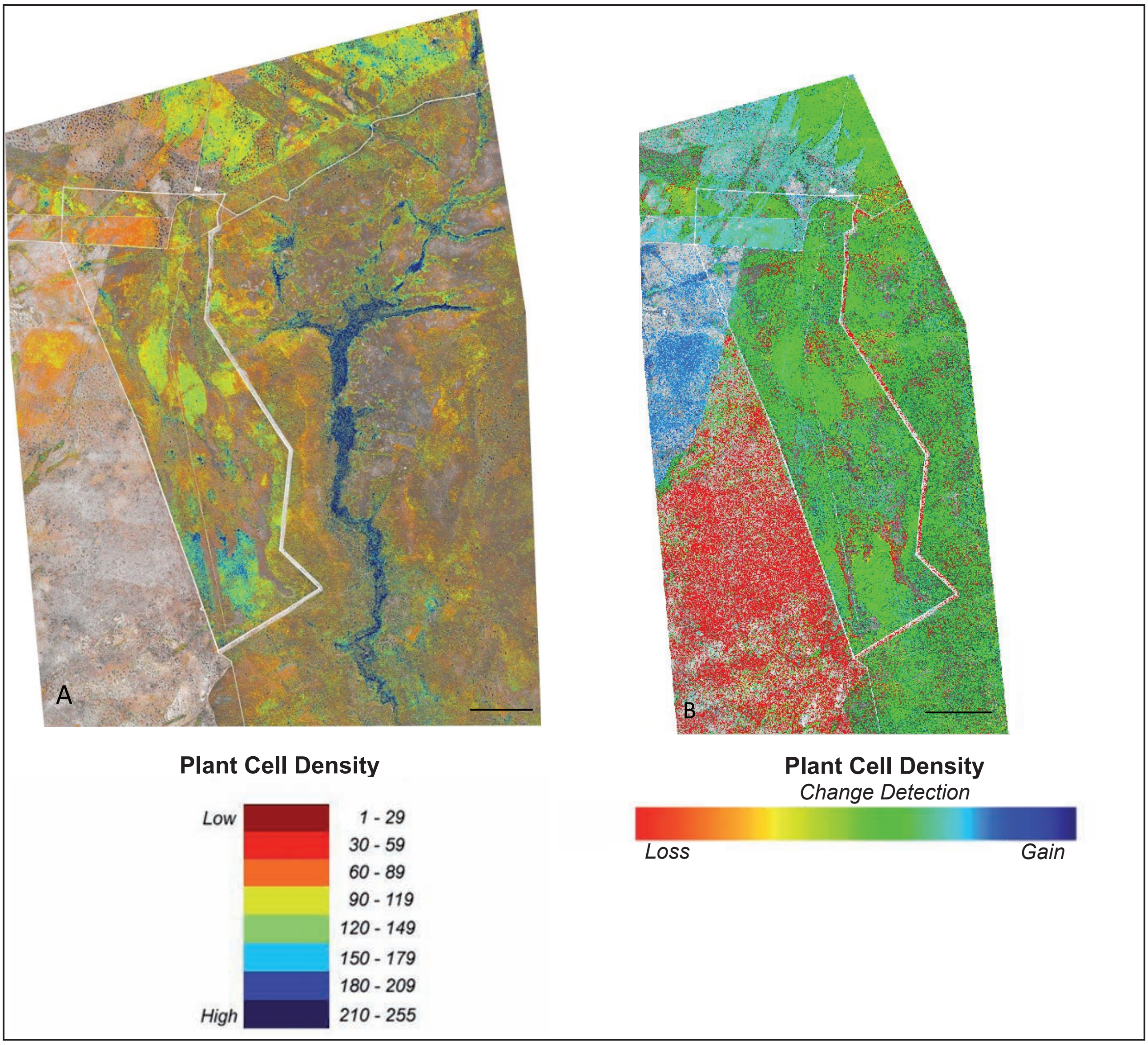

FIGURE 6: Digital Multi-Spectral Imagery graphic showing: (A) the plant cell density at the Bell Track Phytophthora dieback infestation during April 2009; and (B) the change in plant cell density between 2007 – 2009. Scale bar represents 1000 m.

Approved access is then supervised by the Ranger in Charge of the National Park and is restricted to entry in dry soil conditions only. To support these strict hygiene protocols a number of access controls were established including the installation of an animal exclusion fence, vehicle access gates and the upgrade of tracks for vehicle and equipment access to the infested catchment. To aid wildfire management, a number of four-metre wide fire breaks were constructed on the inside and outside of the fence. Field staff undertook regular checks of contractors to ensure compliance with the required access conditions and use of hygiene procedures.

As the pathogen can spread rapidly in free water, it was important to map the topography of the catchment and model possible overland flow during flood events that could lead to outbreaks of the pathogen in the containment area. Detailed hydrological modelling of the catchment was undertaken, including Light Detection and Ranging (LiDAR) aerial capture that consisted of both a high resolution digital elevation model (DEM) and 0.5 m contours. The software ArcGIS Spatial Analyst® (ESRI, California, USA) was used to define sub-catchment boundaries and drainage connections throughout the Bell Track catchment. This allowed for a comparison of the current *Phytophthora cinnamomi* occurrence in relation to sub-catchment boundaries to determine areas where the pathogen is at greatest risk of spreading into an adjoining sub-catchment. Interpretation of the results from the model indicated that the pathogen was contained within two sub-catchments that were considered to be internally draining due to the presence of four large depressions

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or sumps. It was calculated that these sumps have adequate capacity to hold the run-off volume associated with large rainfall events.

To validate that the sub-catchments were self draining and the large depressions (sumps) had adequate capacity, further modelling of rainfall events in the catchment was conducted using XP Storm® (XP Software, Belconnen, Australian Capital Territory, Australia). This modelling exercise investigated: the hydrological analysis of surface flow rates and volumes based on peak flood rainfall events in the catchment to determine the magnitude and behaviour of water to be contained; and the identification of feasible surface water engineering options to divert and store water during peak flood events and prevent downstream catchment flow. The study examined theoretical average recurrent interval (ARI) rainfall events with frequency intervals of 50, 300 and 500 years. These ARI events were for single events with a duration of 36 hours. The model estimated that the sumps within the catchment would have sufficient capacity to hold any stream or overland flow during all such extreme rainfall events. The sumps contain a deep sand-soil profile capable of holding any run-off. Sump depth was checked using vehicle mounted drill rigs to describe the soil profile. It was determined that no substantial hydrological engineering was required for water collection if a 1 in 500 year rainfall event occurred. However, some minor water diversion and soil erosion measures were used along Bell Track and the fire breaks surrounding the infestation to ensure that these cleared areas did not lead to significant run-off.

To aid pathogen containment to its current boundaries within the sub-catchments, root-impervious membranes were installed and vegetation destruction was conducted at areas considered at high risk of rapid pathogen extension. The aim was to disrupt the ability for the pathogen to be spread via root to root transmission between host plants. Root-impervious membrane was installed along the south-western edge of the infestation and the infested area within the south-west sump. This approach was similar to that used by Dunstan et al. (2010) at Cape Riche near the Fitzgerald River National Park. The membrane was a high-density polyethylene (HDPE) root barrier (100 cm deep x 1 mm thick) buried to ca. 90 cm depth and located 2 – 5 m forward of, and parallel to the disease front.

The root-impervious membranes were installed in association with localised vegetation removal in a 2 – 8 m wide strip that aimed to further decrease the opportunity of root to root pathogen transmission. To determine an adequate size for the vegetation removal, the root system of a representative sample of vegetation was examined by air spading (Air-spade®, Guardair USA). The results showed that plant roots of common overstorey species did not extend beyond 8 m from the base of the tree. The effect of vegetation removal on increased soil moisture conditions was also investigated and it was found that vegetation removal led to significant increase in soil moisture (up to 400%). To maintain this break in root connectivity at the locations where the root-impervious membranes were installed, Polyvinylchloride (PVC) irrigation (20 mm diameter) was installed in 200 m lengths underneath the membrane. The fungicidal fumigant sodium methyldithiocarbamate (metham sodium; CAS no. 137-42-8) was applied to this irrigation at 133 g m^{-1} once a year during the winter months when adequate soil moisture for perforation of the fumigant through the soil profile was present to promote sterilisation.

Programme 3: Reduce the impact of the pathogen within the infested areas

Salts of phosphonic acid or phosphite acts as a biodegradable fungicide that protect plants against the impacts of *Phytophthora cinnamomi* and other *Phytophthora* species (Graham, 2011; Guest & Bombeix, 1984; Guest & Grant, 1991; Komorek et al., 1997; Pilbeam et al., 2000; Shearer & Fairman, 1991; 2007a; 2007b; Shearer, Crane & Cochrane, 2004; Shearer, Fairman, & Grant, 2006; Wilkinson et al., 2001). Phosphite works by boosting the plant's own natural defences and thereby allowing susceptible plants to survive within *P. cinnamomi* infested sites (Guest & Bombeix, 1984; Guest & Grant, 1991).

Phosphite (Chemphos 400, Imtade Australia) is regularly applied aerially by the DEC to protect rare and threatened plant species across the south coast of WA (Gillen & Grant, 1997; Barrett, 1997). Phosphite was initially applied as an aerial low-volume spray, at a rate of 24 kg active ingredient (phosphonic acid, monopotassium salt) per ha, at the Bell Track infestation in 1997 and subsequently on a once to twice yearly basis since. The majority of this treatment has been strategic, targeted low-volume aerial spray as the cost of treating the entire infestation was cost prohibitive. However, in addition to aerial spraying of phosphite, some on-the-ground low-volume foliar spraying and high concentration (30% active ingredient) basal bark spraying of phosphite has been conducted in areas of greatest risk of disease outbreak.

A number of studies have demonstrated that phosphite reduces mortality in *Phytophthora cinnamomi* infested sites from the south-west of WA (Barrett, 2003; Shearer, Crane & Fairman, 2004; Shearer, Fairman, & Grant, 2006; Shearer & Fairman, 2007). Monitoring of the long-term efficacy of phosphite treatment within the Bell Track infestation has shown the fungicide treatment to significantly reduce mortality in keystone species such as *Banksia baxteri* and *Lambertia inermis* (Barrett pers. comm.). Phosphite also has the added benefit of retarding disease centre expansion where

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transmission is largely due to root to root transmission. Shearer, Crane and Fairman (2004) demonstrated that phosphite can reduce rates of disease centre expansion in *Banksia* L.f. woodland from 1.3 ± 0.1 m for untreated sites to 0.6 m ± 0.1 m in treated sites. Further, Dunne et al. (2010) has shown that phosphite treatment can also indirectly reduce soil *P. cinnamomi* inoculum levels. Therefore, the premise for maintaining on-going phosphite treatment at Bell Track is to reduce disease, assist in containment by reducing the rate of disease centre expansion, and reduce soil inoculum levels.

Strategic re-vegetation was conducted in 2008 in the southern half of the infested area. The impact of *Phytophthora cinnamomi* in this southern half had resulted in significant loss of structure and biomass as bare ground was now common in the infested area. The aim of the re-vegetation was to rapidly re-establish mid and upper storey canopy cover, thereby reducing surface overland water flow and water stored within the soil profile therefore reducing the rate of disease expansion. At close inspection, the majority of the infested area had already shown some natural regeneration by tolerant species, so remaining areas of bare ground were planted with the selected *P. cinnamomi*-tolerant species.

Five plant species were selected for the re-vegetation program based on: their resistance to *Phytophthora cinnamomi;* their growth form (i.e. plants were all small shrubs over 0.5 m tall); and their occurrence locally. These five species were: *Acacia myrtifolia* Sm.; *Calothamnus quadrifidus* R.Br.; *Eucalyptus pleurocarpa* Schauer; *Melaleuca nesophila* F. Muell; and a small number of *Hakea victoria* J. Drumm. Plant species were sourced from a nursery that had industry accreditation for good hygienic practices and a subsample was checked to ensure the stock was free of *Phytophthora* species. The five species were planted at locations 20 m apart along east-west transects across a 20 ha area at the southern end of the infested area.

Programme 4: Science-based investigations

A range of different scientific investigations and research were conducted to provide insight into the hydrological features of the site and to describe the epidemiology and biology of the pathogen. This was essential to ensure decisions on site management of the pathogen were based on accurate knowledge, thereby reducing the likelihood that the pathogen will spread outside of its current catchment. For example, research into hydrological features of the site allowed for evaluation of the assumptions made during the hydrological modelling of the catchment including the rainfall scenarios used in the model. Specifically, three WatchDog425® weather stations (Spectrum, USA) were established across the catchment to monitor rainfall events and link these events to changes in disease centre expansion. Further, soil and vegetation types were mapped across the catchment to provide data to model future pathogen spread, predict impact and ensure containment techniques are appropriately deployed.

A number of field experiments were conducted to describe the biology and epidemiology of *Phytophthora cinnamomi* at the Bell Track infestation. The knowledge gained during this research has been directly utilised during the Bell Track containment project. Experimental questions within these trials aimed to improve mapping, detection, buffers and management techniques.

A number of phosphite field trials have also been established at the Bell Track infestation. These trials have investigated the effect of High Intensity Phosphite Application (HIPA) on the epidemiology and disease caused by *Phytophthora cinnamomi*. The HIPA approach has been demonstrated to reduce disease centre expansion, reduce pathogen inoculum within the soil profile and reduce mortality in susceptible species (Dunne et al., 2010).

Protecting currently non-infested area across the Fitzgerald River National Park

To ensure that the efforts to contain the Bell Track infestation from infesting other parts of the Park were not in vain, it was essential to conduct a rigorous survey of the Park and surrounding area for the presence of other *Phytophthora cinnamomi* infestations. This included: broad helicopter surveys of the land adjacent to the major river systems and landforms within the wilderness area; linear surveys of tracks, trails and roads within the Park's boundaries and surveys in the road network surrounding the Park; assessment of sand and gravel quarries; Park visitor and management facilities surveys; and other opportunistic sampling. This additional sampling identified two infestations within the Park that are currently undergoing eradication and containment management efforts. These infestations are unrelated to the Bell Track infestation and are likely to have been introduced in separate events. Further, this sampling identified a high level of infestation of the road network to the east of the Park. In response to this external threat, a risk reduction plan has been developed by South Coast Natural Resource Management Incorporated to engage stakeholders to prevent any future accidental introduction into the Park.

Conclusion

To date, this project has utilised a comprehensive, well integrated range of management techniques for containing *P. cinnamomi* within its current extent at the

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Bell Track catchment in the FRNP, thus protecting the largely disease free status of the National Park. Future monitoring will be continued and the management techniques sustained to ensure the pathogen is contained to the current catchment.

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