RESEARCH REPORT

Rainforest Dieback Mapping and Assessment

2004 Monitoring Report Including an Assessment of Dieback in High Altitude Rainforests

Stuart J. Worboys

Rainforest CRC

Cooperative Research Centre for Tropical Rainforest Ecology and Management

RAINFOREST DIEBACK
MAPPING AND ASSESSMENT

2004 MONITORING REPORT INCLUDING AN ASSESSMENT OF DIEBACK IN HIGH ALTITUDE RAINFORESTS

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WET TROPICS MANAGEMENT AUTHORITY

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Cover Images ©
(*Top*) Rainforest CRC.
(*Centre*) Healthy rainforest canopy near Cape Tribulation, north Queensland. Image courtesy Shannon Hogan.
(*Bottom*) Dieback near the northwest peak of Mount Bartle Frere, north Queensland, December 2002.

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ACKNOWLEDGEMENTS

This project was funded by the Wet Tropics Management Authority (WTMA), with substantial support from the Rainforest CRC, School of Tropical Biology, James Cook University and Queensland Parks and Wildlife Service (QPWS).

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EXECUTIVE SUMMARY

Significant Findings

- Dieback has been confirmed as being associated with walking tracks on both Mount Bartle Frere and Mount Bellenden Ker.
- Several sites were categorised as suffering from severe dieback.
- Dieback and pig damage were confirmed for walking track environs on both Mount Bartle Frere and Mount Bellenden Ker, but not observed remote from the tracks.
- *Phytophthora cinnamomi* was confirmed as being associated with dieback, except in two ambiguous instances.
- Three plant families, Lauraceae, Myrtaceae and Proteaceae, have a high proportion of species with some degree of field susceptibility to *Phytophthora*-related dieback.
- Several listed threatened plant species appeared to have some degree of field susceptibility to *Phytophthora*-related dieback. Some endemic species with extremely restricted geographical ranges were also affected.

Management Implications

The organism, *Phytophthora cinnamomi* is present along walking tracks in high-altitude rainforests of the Wet Tropics where it appears to impact upon restricted endemic and listed threatened floral species. It is also present in some undisturbed areas of the region.

The significance of the impacts of the *Phytophthora cinnamomi* organism on the rainforests of the region is still not fully understood. It is still not known if the organism is indigenous to the region (although the author considers this unlikely); if there is a relationship between *Phytophthora*-related dieback and the recent drought conditions; or if there are synergistic interactions between *P. cinnamomi* and other *Phytophthora* species present in the soils of the Wet Tropics.

Despite these considerations, the devastating impacts of *P. cinnamomi* on native ecosystems at a national scale cannot be ignored; a precautionary approach is required for the Wet Tropics until the pathogen's impacts are more fully understood. Management actions are required, however, in developing these actions a conservative approach has been followed as far as possible. Only new works in remote areas will trigger the implementation of management actions, which will have multiple benefits, most notably preventing the introduction of weeds.

Where management actions impact on forest users (researchers and recreational walkers), it is anticipated these will only affect a small number of users and the required actions are not onerous (i.e. cleaning footwear before leaving an infected site).

Recommendations

The following recommendations are made in addition to those given in Gadek and Worboys (2003) and Worboys and Gadek (2004):

1. Future dieback monitoring should be undertaken utilising the monitoring procedure outlined in this document and detailed in the *Guide to Monitoring* Phytophthora*-related Dieback in the Wet Tropics of North Queensland* (Worboys 2006).
2. The criteria for high susceptibility zones to be modified to include areas above 1,050 metres altitude. Specifically, the modified criteria will state:

   High susceptibility zones:

   - Notophylls or microphylls dominant;
   - Altitude greater than 750 metres; and
   - Located on soils derived from acid igneous rocks.

3. Monitoring of the health of all sites is to be continued, with particular focus given to the impacts of dieback on rare, endemic plant species occurring in high altitude forests.
4. The soil sampling program is to be continued with up to five samples being tested from each site. The costs and logistics of having soils tested must be discussed with Grow Help Australia (or another suitable testing agency) prior to the commencement of the project. The soil sampling protocol should be altered slightly so that samples are taken from the centre of five of the monitoring plots within each site to avoid measuring the same points year after year.

Two other recommendations are given here that relate specifically to activities on mountaintops. The first, the disinfecting of footwear, is not onerous and requires less than five minutes' work by individuals who carry a small brush and some methylated spirits into the field for use when cleaning. It is not anticipated this recommendation will impact on a large proportion of walkers; it can best be implemented through targeted education programs. The second recommendation arises from the isolation of *P. cinnamomi* around the telecommunications infrastructure near the peak of Mount Bellenden Ker.

5. A requirement should be placed on walkers in highland areas (specifically, Mount Bellenden Ker, Mount Bartle Frere, Carbine Tableland and Thorntons Peak) to disinfect footwear and other mud-bearing materials if they plan to deviate significantly from existing tracks.
6. All maintenance works on and around the Mount Bellenden Ker cableway should be conducted according to strict hygiene protocols, as recommended in Worboys and Gadek (2004), to limit the spread of *P. cinnamomi* from infested areas.

1. INTRODUCTION

1.1 BACKGROUND

Dieback caused by *Phytophthora cinnamomi* has had a devastating impact on forests, heathlands and woodlands across the wetter areas of Australia (Environment Australia 2001). The pathogenic, root-rotting, fungus-like organism is believed to have been introduced following European settlement and now affects hundreds of thousands of hectares of native vegetation, impacting significantly on biodiversity values and threatening the survival of some species. In response to the threat it poses to biodiversity at a national scale, *Phytophthora cinnamomi* has been identified as a 'Key Threatening Process' under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999.* A National Threat Abatement Plan (Environment Australia 2001) has been developed to prioritise actions for its control. The Threat Abatement Plan is due for review in 2006.

Until recently, much of the focus upon the impacts of *P. cinnamomi* has been directed at the southern states, in particular, the southwest areas of Western Australia. However, significant areas of patch death have been identified in the upland rainforests of northern Queensland (Figure 1; also see Gadek 1999). A strong association between *P. cinnamomi* and this patch death has been established (Gadek 1999).

In response to increasing concerns regarding the impacts of *P. cinnamomi* on upland and highland rainforests in the Wet Tropics and its potential for spread by tourism and management activities, investigations into its impacts were initiated in 1997.

Implementing actions that address the goals of the Threat Abatement Plan poses problems in the Wet Tropics. The level of threat posed to native species and communities by *P. cinnamomi* is difficult to assess, as significant gaps exist in the knowledge of dieback in the Wet Tropics. To address these gaps, a monitoring program has been established. The monitoring program commenced in 2002 and the outcomes of that monitoring round were reported in Gadek and Worboys (2003).

Gadek and Worboys (2003) highlighted the need to continue the monitoring of patch death areas and also expressed strong concern regarding the presence of dieback on high altitude ridgelines in the Wet Tropics. The Wet Tropics Management Authority (WTMA) funded additional investigations in 2004 to address these concerns. Terms of Reference (Section 1.3) were drawn up to guide these works.

This report documents the results of dieback monitoring that was undertaken between April and June 2004, and provides a discussion of the outcomes of the monitoring site assessments established on Mount Bartle Frere. Also included is a report of the results of investigations undertaken on high altitude ridgelines on Mount Bellenden Ker.

It addresses reporting requirements of Program B (Section 1.3.2), and the reporting requirements resulting from the monitoring undertaken at Koombooloomba / Tully Falls, Lamb Range and Mount Lewis.

1.2 MONITORING PROGRAM DESIGN

Monitoring sites were established in upland forests in 2002 in order to ground-truth mapped dieback polygons detected from aerial photograph interpretation. Data from ground-truthing would be used to undertake an assessment of the feasibility of remote sensing for determining the spectral characteristics of known instances of patch death and their applicability for detailed forest health and ongoing monitoring of the phenomenon.

Sites were selected using the following criteria (in order of priority):

a) Located within a mapped dieback polygon (Figure 1);

b) Significant dieback of forest canopy observable from the centre of the site; and

c) Ease of access.

On-ground investigations encountered significant difficulties in identifying the sites marked on aerial photography and correlating the observed canopy health with that seen from the ground. However, when considered on its own, the data provided a useful indication of the extent of *Phytophthora*-related dieback in upland Wet Tropics rainforests.

Investigations into the spatial extent of dieback-affected forest were not undertaken in the 2002 surveys, because the diffuse nature of canopy death at most sites prevented clear boundaries from being demarcated. The design of the monitoring program was therefore aimed at assessing the long-term impact of *Phytophthora*-related dieback on structure and species composition of set size plots. However, the establishment of monitoring sites in well-defined dieback-affected forest sites on Mount Bartle Frere provided an opportunity to observe the rate of spread of dieback (if any) over time. Consequently, monitoring sites were established so as to provide data that would be directly comparable to the 2002 monitoring sites, but also act as transects along which plant health could be directly tracked over time.

1.3 TERMS OF REFERENCE

In response to the concerns raised in Gadek and Worboys (2003), the development of specific monitoring programs is proposed. The programs aim to utilise existing expertise and research information to:

Program A

A1. Develop a framework for a Dieback Monitoring System for the Wet Tropics to monitor recovery or further progression of vegetation post dieback. The monitoring program needs to be scientifically robust but also be designed to be user-friendly for Queensland Parks and Wildlife Service (QPWS) ranger staff so the monitoring can be maintained over a long-term basis by QPWS.

A2. Revisit and assess existing dieback monitoring plots at Koombooloomba / Tully Falls, Lamb Range and Mount Lewis, as described in Gadek and Worboys (2003) for suitability as sites for this program.

A3. Develop robust pro-formas and indicators to measure the impact and recovery of dieback at selected sites.

A4. Involve land managers at all levels, in particular training of on-ground staff in developing robust and practical procedures for assessing and monitoring dieback in the field.

Program B

B1. Assess the level of risk of forest dieback in mountaintops and highland areas within the World Heritage Area, specifically the mountaintops at Bellenden Ker and Bartle Frere.

B2. Consult relevant experts regarding the distribution and movement of feral pigs in the upland and highlands areas of the World Heritage Area with the view to providing an indication of the anticipated potential of pigs being a vector for *Phytophthora cinnamomi* in these higher altitudes.

B3. Involve land managers at all levels, in particular training of on-ground staff in developing robust and practical procedures for assessing and monitoring dieback in the field.

1.4 OUTPUTS

Program A

1. Selected monitoring plots properly marked for long-term monitoring;
2. Monitoring and recording manuals (a sufficient number for rangers) which include:
    a. Collector and user information;
    b. Survey and analysis methodology; and
    c. Survey pro-forma.
3. Program report including an executive summary, background, methods, findings, references and an outline of further research needs, management implications of the research findings and recommended management responses.

Program B

4. Program report including an executive summary, background, methods, findings, references and an outline of further research needs, management implications of the research findings and recommended management responses.

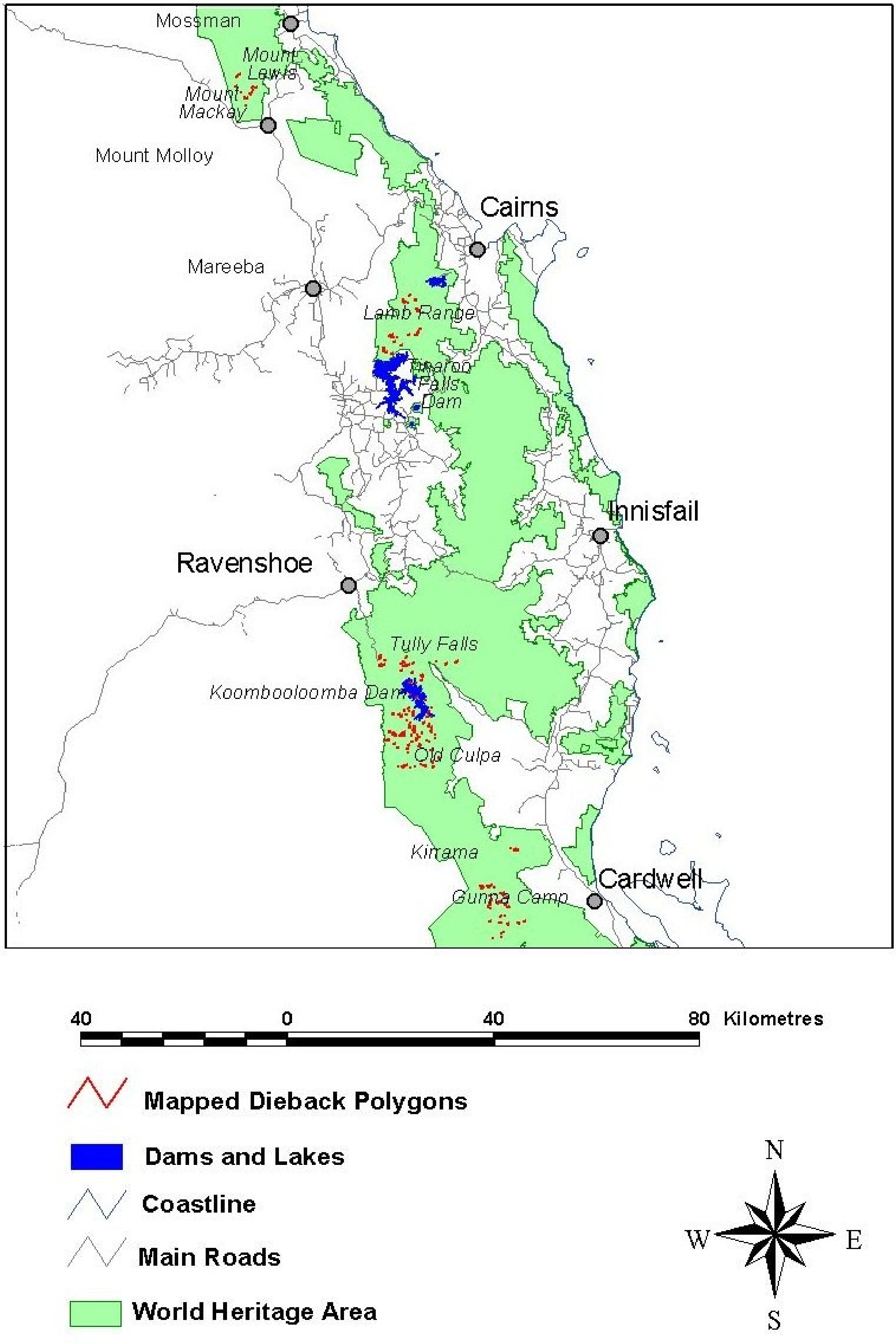

Figure 1: Mapped dieback polygons in the Wet Tropics World Heritage Area. Mapped dieback polygons delineate locations in which smaller patches of dead and dying canopies can be detected.

2. METHODS

2.1 SITE SELECTION

Gadek and Worboys (2003) recommended continued monitoring of the sites established in 2002, but further recommended the establishment of sites on high-altitude ridgelines. This lead to the creation of monitoring sites in previously identified patch death areas on Mount Bartle Frere and an inspection of high altitude ridgelines on Mount Bellenden Ker for evidence of *Phytophthora*-related dieback.

2.1.1 Mount Bartle Frere

Several obvious dieback affected sites are to be found on the Mount Bartle Frere western access track. This area is located at high altitude to the west of the North West Peak. In 2004, two monitoring sites within dieback-affected areas of forest were established as well as a control site in nearby unaffected forest.

2.1.2 Mount Bellenden Ker

The main ridgeline to the south of the centre peak of Mount Bellenden Ker is the location of a substantial telecommunications facility (marked as 'radio mast' in Figure 2). The presence of *P. cinnamomi*-related dieback on Mount Bellenden Ker has not been reported, although concerns have been raised regarding the potential for its introduction via people accessing the telecommunications facility on the mountaintop. Consequently, in May 2004, access tracks near the centre peak of the mountain and nearby trackless ridgelines were examined for forest patches exhibiting symptoms of dieback.

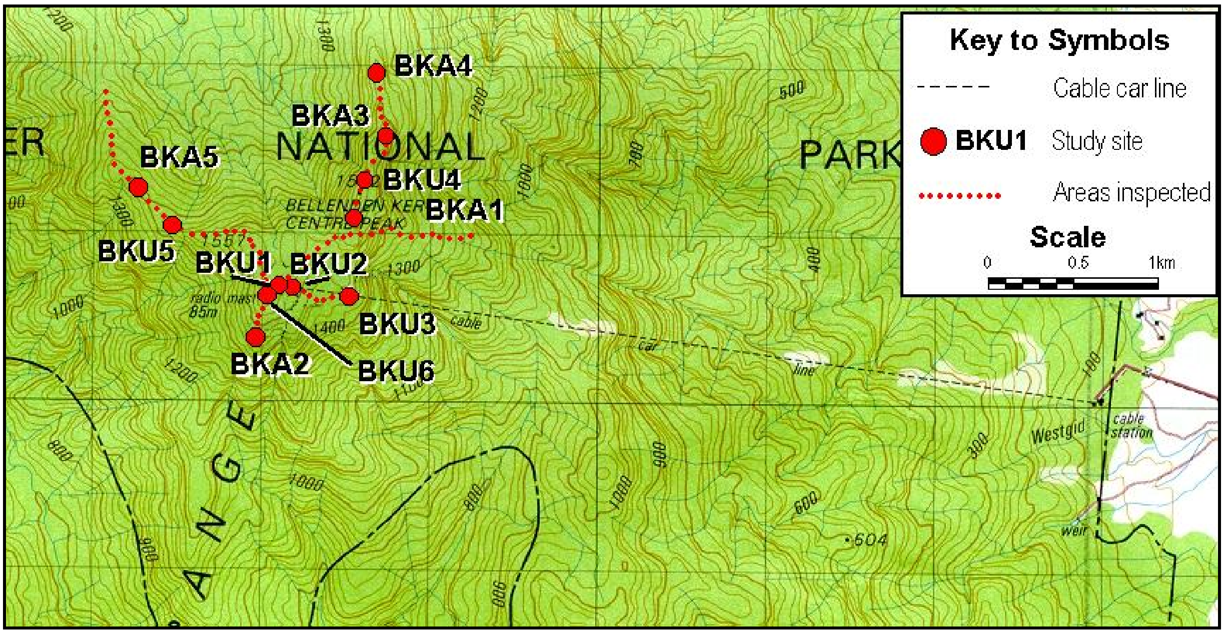

Figure 2: Map of Mount Bellenden Ker and the cable car alignment, showing study sites and ridgelines inspected for symptoms of dieback. Scale is indicated by one-kilometre squares. Source: Royal Australian Survey Corps (1986).

2.1.3 Other Areas

Study sites and monitoring sites were established in a number of upland rainforest areas in 2002. In total, 33 study sites were identified and described in Gadek and Worboys (2003, p. 26). Of these, thirteen were marked as long-term monitoring sites, specifically:

- Sites CO03, CO04, PO03, PO05, PO06 and JP04 (Pilot Study) in the Koombooloomba / Tully Falls area;
- Sites LRU1, LRA1 and LRA2 in the Lamb Range area; and
- Sites MLU6, MLA1, MLA4b and MLA14 in the Mount Lewis area.

The location of these monitoring sites is illustrated and described in detail in Gadek and Worboys (2003) and in the *Guide to Monitoring* Phytophthora*-related Dieback in the Wet Tropics of North Queensland* (Worboys 2006).

Table 1: List of study sites and the research tasks carried out in 2002 and 2004.

Study Site		Year in which task was completed			
		Baiting of Soils	Site Description	Soil Profile	Canopy Composition
Koombooloomba / Tully Falls	CO03	2002, 2004	2002	2002	2002
	CO04	2002, 2004	2002	2002	2002
	PO03	2002, 2004	2002	2002	2002
	PO05	2002, 2004	2002	2002	2002
	PO06	2002	2002	2002	2002
	JP04 (Pilot Study Site)	2004	2002	-	2002
Lamb Range	LRU1	2004	2002	2002	2002
	LRA1	2004	2002	2002	2002
	LRA2	2004	2002	2002	2002
Mount Lewis	MLU6	2002, 2004	2002	2002	2002
	MLA1	2002, 2004	2002	2002	2002
	MLA4b	2002, 2004	2004	2002	2002
	MLA14	2004	2002	2002	2002
Mount Bartle Frere	BFU1	2004	2004	-	2004
	BFA1	2004	2004	-	2004
	BFA2	2004	2004	-	2004
Mount Bellenden Ker	BKU1	2004	2004	-	-
	BKU2	2004	2004	-	-
	BKU3	2004	2004	-	-
	BKU4	2004	2004	-	-
	BKU5	2004	2004	-	2004
	BKU6	2004	2004	-	-
	BKA1	2004	2004	-	2004
	BKA2	2004	2004	-	2004
	BKA3	2004	2004	-	2004
	BKA4	2004	2004	-	-
	BKA5	2004	2004	-	2004

2.2 TASKS UNDERTAKEN AT STUDY SITES

Table 1 describes the research tasks undertaken at each of the study and monitoring sites in 2004. Note that the Kirrama / Cardwell Range sites were abandoned on the basis that similar forest communities were being monitored in the Lamb Range and Koombooloomba / Tully Falls areas, therefore the time involved in accessing the Kirrama / Cardwell Range sites could be better spent at the other sites. Site PO03 was abandoned due to an infestation of stinging trees and *Calamus*. On the other hand, new monitoring sites were established on Mount Bartle Frere and investigations of the dieback on the ridgelines of Mount Bellenden Ker were undertaken. Monitoring sites were not established on Mount Bellenden Ker, however canopy composition was assessed at a number of soil sampling points.

2.3 SOIL BAITING

Testing of soil samples for the presence of *Phytophthora cinnamomi* was carried out in Brisbane by Grow Help Australia. Soils samples were sealed in zip-lock bags and kept cool, but not cold, until they could be despatched. Samples were packed in insulated foam boxes and delivered to Grow Help Australia within fourteen days of collection.

Grow Help Australia described their baiting procedure as follows:

> *"[E]ach soil sample [was] lupin seedling bait tested to check specifically for the presence of* Phytophthora *species.*
>
> *Lupin seedlings showing any signs of rotting [were] cultured... onto* Phytophthora *and/or* Phytophthora–Pythium *selective media. Rotted lupins [were] also… microscopically examined for presence of* Phytophthora sporangia*.*
>
> *Any isolates detected by the baiting method [were] confirmed as* Phytophthora *by examination of sporangia in most cases. Full identification to species [was] not done as part of this job. However, Leif Forsberg [commented] on whether isolates [had] characteristics similar to* Phytophthora cinnamomi *based on some morphological characteristics observed."*

2.4 SITE DESCRIPTIONS

The site description is a general overview of site characteristics and was assessed for an area within twenty metres of the central point. For each site noted in the task list (Table 1), the following physical features were noted:

- UTM grid reference and altitude (using GPS where possible). Datum = AGD 1966[1];
- Substrate (parent material);
- Topsoil description;
- Landform element of the site (descriptions consistent with McDonald *et al.* 1994).
- Disturbance (natural and anthropogenic);
- Forest structure and physiognomy; and

[1] AGD coordinates provided here allow direct reference to the 1:50,000 topographic maps available for the Wet Tropics.

- Where possible, notes on dominant and/or conspicuous plant species.

2.4.1 Forest Structure

Forest structure was described and the Tracey (1982) forest type determined for each site. Queensland Herbarium vegetation maps were used to check type determinations. The corresponding Regional Ecosystem (RE) (Sattler and Williams 1999) was identified and the conservation status of the RE was ascertained with reference to the Queensland *Vegetation Management Regulation 2000.*

The biodiversity status of the RE, as defined in the regional ecosystem description database (Environmental Protection Agency 2004), is also presented. Biodiversity status provides an indication of the overall capacity of a defined regional ecosystem to maintain viable populations of species that are characteristic of that RE.

2.4.2 Site Health

The health of each study site was visually assessed and rated using a modification of the method of Gadek *et al.* (2001, p.27). The ratings used are defined as follows:

Severity of Dieback

0 = insignificant with very few plants showing signs of leaf chlorosis or branch death;

1 = slight, with several plants showing signs of leaf chlorosis or branch death;

2 = moderate (many plants as above, or some plants apparently dead or dying);

3 = severe (many dead plants or gaps indicating loss of vegetation).

Tree Fall Damage

1 = none;

2 = slight (affecting small area of site only);

3 = moderate;

4 = severe (affecting most of site).

Site Drainage

1 = poorly drained;

2 = well drained;

3 = rapidly drained.

Disturbance to Soil Surface

1 = insignificant;

2 = minor (small area of digging/disturbance);

3 = moderate (moderate or severe digging in small area);

4 = severe (most of site).

2.4.3 Soil Profiles

The colour and texture of the A1 horizon was recorded.

2.4.4 Tree Health Assessments

Tree health assessments were carried out utilising the method of Gadek and Worboys (2003). This method was refined by Worboys (2004). In contrast to site descriptions, data for tree health assessments were collected on a plot-by-plot basis. Each study site was divided into between eight and twenty 10m x 10m plots. The health of all trees more than two centimetres diameter at breast height (dbh) within the plot was assessed using the following scale:

Tree Health Scale	Definition
1	Tree healthy. Less than ten percent of branches in the canopy have lost their leaves.
2	Tree with slight canopy thinning. Between ten and fifty percent of branches in the canopy have lost their leaves.
3	Tree with significant canopy thinning. Greater than fifty percent of branches in the canopy and twigs have lost their leaves. Includes trees that are entirely dead in the canopy, but have some coppice shoots coming from the base of the trunk.
4	Tree recently dead. No living coppice shoots. Some dead leaves still present on tree.
5	Tree dead, and trunk greater than three metres tall. No leaves present.

2.4.5 Tree Size Classes

The trees were assigned to a size class using the following scale:

Size

Size Class Scale	Trunk Diameter	Trunk Circumference
1	2cm-10cm	6.3cm-31.4cm
2	10cm-30cm	31.4cm-94.2cm
3	30cm-50cm	94.2cm-157cm
4	>50cm	>157cm

Size classes were used as they allowed for a more rapid assessment of tree size. For calculations of stem basal area at each site, the $\Sigma(\text{size class})^2$ was assumed to be directly proportional to actual basal area.

An estimate of tree height was incorporated for all trees assessed. The goal of this was to distinguish trees that could be considered canopy trees.

2.5 FLORISTIC AND CANOPY COMPOSITION – MOUNT BARTLE FRERE SITES

2.5.1 Floristics

Floristic and canopy composition has been documented for most study sites (see Table 1; Gadek and Worboys 2003) and was not considered necessary for the current year's assessments, though wherever possible within the time available, the tree species were identified during the assessments at all study sites. Most stems were classed as 'unknown'.

We undertook full assessments of canopy composition at all Mount Bartle Frere monitoring sites and some Mount Bellenden Ker study sites (see task list in Table 1). All tree species greater than two centimetres dbh were identified.

2.5.2 Species Diversity

An indication of species diversity at each study site was provided by both the gross number of species present at the site and the Shannon-Wiener diversity index (Kent and Coker 1995) in the format shown below. A diversity information index is considered vitally important in terms of analysis of monitoring data over time, as it indicates change in relative species composition for a site. The method of calculation presented here does not take into account the cover contributed by each species.

$$H = -\sum_{i=1}^{S} (p_i)(\ln p_i)$$

H = Index of species diversity

S = Number of species

p_i = Proportion of the total sample belonging to the *i* 'th species

Kent and Coker (1995)

2.5.3 Successional Status

To obtain an indication of the successional status of the community at each site, two measures were employed. The first was *tree size* (see Section 2.4.5), and the second was to assign a 'successional status' code to each species identified in the surveys. Codes were derived from distribution and ecology notes provided in Hyland *et al.* (1999). The codes and criteria used to assign the codes were:

Successional Status Category	**Criteria** The text of Hyland *et al.* (1999) describes the species as:	**Examples**
1	• Favoured by disturbance; • Characteristic component of rainforest regrowth; and • Regrowth species in disturbed rainforest.	*Acronychia acidula;* *Dendrocnide moroides;* *Polyscias Australiana.*
2	• Grows in a variety of rainforest types.	*Uromyrtus metrosideros;* *Rhodamnia sessiliflora.*
3	• Grows in well-developed rainforest.	*Gillbeea adenopetala;* *Guioa montana;* *Cryptocarya bellendenkerana.*
4	• Grows in undisturbed rainforest.	*Triunia montana;* *Harpullia frutescens.*
No code	• Species not described in Hyland *et al*. (1999); and • Successional status not clear or sufficiently specific in the distribution and ecology notes.	Most vines, ferns and orchids; *Baloghia inophylla;* *Alyxia orophila;* *Alpinia arctiflora.*

2.6 ANALYSES

A framework exists for the analysis and presentation of data (Gadek and Worboys 2003). The availability of this report should somewhat simplify the reporting process.

3. RESULTS – MOUNTAINTOP SITES ONLY

3.1 SITE DESCRIPTIONS

The following section provides site descriptions for the newly established monitoring sites on Mount Bartle Frere and for soil sampling points on Mount Bellenden Ker.

3.1.1 Mount Bartle Frere Western Access Track

Patches containing dead and dying canopy trees were observed at a number of locations on the Mount Bartle Frere Western Access Track, near the northwest peak of the mountain. These were most apparent at altitudes above 1,400 metres (Table 2). Study sites were established on the walking track, with transects oriented perpendicular to the alignment of the track.

Table 2: Physical description of monitoring sites on Mount Bartle Frere.

Site Code and Locality Name	Survey Date	UTM Grid Coordinates	Altitude	Landform	Forest Type / Regional Ecosystem
BFU1 Northwest peak of Mount Bartle Frere	13/05/04	Estimated at 55K 372935, 8077139	1,420 m	East-west trending ridgeline with moderately inclined to steep falls to the north and south.	Type 9 (Microphyll Vine-Fern Forest) RE 7.12.19
	Canopy to twenty metres. Shrubs and *Cyathea rebeccae* prominent in understorey. Prominent canopy species include *Myrsine oreophila*, *Musgravea stenostachya*, and *Pouteria singuliflora.* Monitoring site lies across the Mount Bartle Frere Western Access Track.				
BFA1 Northwest peak of Mount Bartle Frere	12/05/04	Estimated at 55K 373266, 8077125	1,432 m	East-west trending ridgeline with moderately inclined to steep falls to the north and south.	Type 9 (Microphyll Vine-Fern Forest) RE 7.12.19
	Severely diseased canopy to twenty metres. Shrubs, slender lianes and *Cyathea rebeccae* prominent in understorey. Prominent canopy species include *Musgravea stenostachya*, *Eleaocarpus ferruginiflorus* and *Syzygium wesa.* Monitoring site lies across the Mount Bartle Frere Western Access Track.				
BFA2 Northwest peak of Mount Bartle Frere	13/05/04	Estimated at 55K 373030, 8077139	1,420 m	East-west trending ridgeline with moderately inclined to steep falls to the north and south.	Type 9 (Microphyll Vine-Fern Forest) RE 7.12.19
	Canopy to 25 metres, with diseased trees occasional or uncommon but conspicuous. *Laccospadix australasica* and *Cyathea rebeccae* prominent in the understorey. Monitoring site lies across the Mount Bartle Frere Western Access Track.				

Landform

Mount Bartle Frere lies at the southern end of the Bellenden Ker Range, a very wet and cloudy upland and highland granite massif (Sattler and Williams 1999). The topography of the area is steep to very steep and mountainous. At 1,622 metres, Mount Bartle Frere is Queensland's highest peak. Rainfall on Mount Bartle Frere, although not recorded, is likely to be similar to that of Mount Bellenden Ker, averaging over eight metres per year.

Forest Structure

The forest around each study site was classed as Type 9 (Simple Microphyll Vine-Fern Forest), as defined by Tracey (1982). This corresponds with Regional Ecosystem (RE) 7.12.19 (Simple notophyll vine forest on cloudy wet granite highlands) (Sattler and Williams 1999) (Table 3).

Table 3: Regional Ecosystems containing dieback study sites on Mount Bartle Frere.

Regional Ecosystem	Tracey (1982) Forest Type	Description (Sattler and Williams 1999)	Biodiversity Status	Conservation Status (VMA)
7.12.19	Type 9	Simple notophyll vine forest on cloudy wet granite highlands.	Not of Concern	Not of Concern

Site Health

Site health ratings are given in Table 4.

Table 4: Site health ratings for Mount Bartle Frere monitoring sites.

Site Code	Severity of Dieback	Tree Fall Damage	Site Drainage	Disturbance of Soil	Percentage of samples at site with positive *P. cinnamomi* response
BFU1	1	1	3	0	20%
BFA1	3	1	3	0	100%
BFA2	3	4	3	0	80%

Soils

Soils at the study sites were derived from underlying granites. Topsoils are generally shallow acidic, sandy clay loams with frequent granite outcroppings.

3.1.2 Mount Bellenden Ker

Mount Bellenden Ker is Queensland's second highest peak, rising to 1,592 metres and lying eleven kilometres northwest of Babinda and fifteen kilometres north of Mount Bartle Frere. Although accessible by foot from the eastern side, the most commonly used means of access is via a cable car, which services telecommunications infrastructure on the mountain (Figure 2). The inaccessibility of the mountain to the general public makes it one of the least visited high peaks in the Wet Tropics, therefore it was targeted in this study to survey the presence of dieback-affected forest situated on high altitude ridgelines.

Despite its inaccessibility, a number of distinct tracks exist on the mountain:

- A well-flagged emergency access track services the telecommunications facility. The track follows the main north-south ridgeline before dropping steeply downhill on an eastward-trending spur about one hundred metres south of Bellenden Ker's centre peak. Site BKA1 is on this track;
- A track also accesses the top three towers of the cable car line. Sites BKU1, BKU2, BKU3 and BKU6 are on this track; and

- A flagged track follows the main western ridgeline from the telecommunications facility, before turning north to access a plane crash site. Site BKU5 is on this track.

Monitoring sites were not established on Mount Bellenden Ker, however observations were made of the forest community surrounding the soil sampling sites, reported here.

Landform

Mount Bellenden Ker lies in the middle of the Bellenden Ker Range, a very wet and cloudy upland and highland granite massif (Sattler and Williams 1999). The topography of the area is steep to very steep and mountainous. Although geographically close to Mount Bartle Frere, it is isolated from that peak by a low saddle of about 300 metres altitude.

Bellenden Ker is Australia's wettest recorded location. The rain gauge placed adjacent to the telecommunications facility on the mountain (recorded by the Bureau of Meteorology as the 'Bellenden Ker Top Station') measures a rainfall of between five and eleven meters annually. The recorded rainfall does not include 'cloud stripping' or 'occult precipitation', which contribute significantly to effective precipitation on high peaks through the interception of cloud cover by moss-laden forest canopies.

Forest Structure

The forest around most of the study sites was mapped as RE 7.12.20, although some, at lower altitude, were located in forest mapped by the Queensland Herbarium as a mix of RE 7.12.16 and RE 7.12.19. Typically, these mixed forest communities were structurally and floristically more similar to RE 7.12.19.

Site Health

Site health ratings are given in Table 6. Sites bearing infrastructure (BKU1, BKU2, BKU3 and BKU6) had been cleared, but bore some regrowth. Consequently, they were not assessed for dieback severity, nor could they be assessed for tree fall damage. Site BKU6, in the grounds of the telecommunications facility, was generally well drained, but some small areas were found to be poorly drained (Table 6).

Soils

Soils at study sites were derived from underlying granites with a shallow O horizon. The A1 horizon in undisturbed sites was typically an acidic sandy clay loam. Granite outcrops were present at some sites, but not as commonly encountered as on Mount Bartle Frere. Sites bearing infrastructure (BKU1, BKU2, BKU3 and BKU6) were frequently contaminated with gravel and concrete fragments.

Table 5: Physical description of monitoring sites on Mount Bellenden Ker.

Site Code and Locality Name	Survey Date	UTM Grid Coordinates	Altitude	Landform	Forest Type / Regional Ecosystem
BKU1 Mount Bellenden Ker Cable Car, Tower 9	17/05/04	Estimated at 55K 378094, 8090700	1545 m	Moderate hill slope on steep granite mountains.	Clear
	Site located at foot of last tower on Mount Bellenden Ker cableway. Cement footings will probablyl result in high soil pH. Vegetation comprises regrowth dominated by *Leptospermum wooroonooran*. No dieback evident in regrowth.				
BKU2 Mount Bellenden Ker Cable Car, Tower 8	17/05/04	Estimated at 55K 378190, 8090688	1548 m	Moderately steep hill slope on steep granite mountains.	Clear
	Site located at foot of second last tower on Mount Bellenden Ker cableway. Cement footings probably will result in high soil pH. Vegetation comprises regrowth dominated by *Leptospermum wooroonooran*. No dieback evident in regrowth..				
BKU3 Mount Bellenden Ker Cable Car, Tower 7	17/05/04	Estimated at 55K 378543, 8090641	1464 m	Moderately steep hill slope on steep granite mountains.	Clear
	Site located at foot of Tower 7 on Mount Bellenden Ker cableway. Vegetation disturbed. Simple microphyll vine-fern thicket. Common species include *Trochocarpa bellendenkerensis*, *Elaeocarpus ferruginiflorus*, *Rhodamnia sericea*, *Flindersia pimenteliana* var. *oppositifolia*, *Tasmannia* sp. (Mount Bellenden Ker), *Rapanea achradifolia*, *Litsea bennettii*, *Maesa dependens* and *Acronychia chooreechillum*. No dieback evident in regrowth.				
BKU4 Mount Bellenden Ker northern ridge	17/05/04	Estimated at 55K 378587, 8091284	1602 m	North-south trending ridgeline on steep granite mountains.	Type 10 (Simple Microphyll Vine-Fern Thicket) RE 7.12.20
	Simple microphyll vine-fern thicket. Canopy dominated by *Leptospermum wooroonooran*. Prominent species in understorey include *Steganthera macooraia*, *Hypsophila halleyana*, *Dracophyllum sayeri*, *Laccospadix australasica*, *Tasmannia* sp. (Mount Bellenden Ker), *Cyathea rebeccae* and *Blechnum* sp.				
BKU5 Mount Bellenden Ker western ridge	19/05/04	Estimated at 55K 377419, 8091115	~ 1392 m	Northwest-southeast trending ridgeline on rolling granite mountains.	Type 9 (Simple Microphyll Vine-Fern Forest) RE 7.12.19
	Access track to plane crash site. Simple notophyll vine canopy to twenty metres. *Syzygium wesa* and *Cinnamomum propinquum* prominent in canopy. Ground ferns and *Cyathea rebeccae* prominent in understorey. No dieback evident.				
BKU6 Mount Bellenden Ker tele-communications facility	19/05/04	Not recorded	Not recorded	Broad, north-south trending ridgeline on steep granite mountains.	Clear
	Site cleared. Telecommunications facility is surrounded on three sides by regularly maintained lawn. No dieback evident.				
BKA1 Mount Bellenden Ker centre peak	17/05/04	Estimated at 55K 378537, 8091112	1587 m	North-south trending ridgeline on steep granite mountains.	Type 10 (Simple Microphyll Vine-Fern Thicket) RE 7.12.20
	Severely diseased patch of simple microphyll vine-fern thicket to eight metres. *Laccospadix australasica* and *Cyathea rebeccae* prominent in understorey. Prominent canopy species include *Myrsine oreophila* and *Elaeocarpus ferruginiflorus*.				

<table>
<tr><th>Site Code and Locality Name</th><th>Survey Date</th><th>UTM Grid Coordinates</th><th>Altitude</th><th>Landform</th><th>Forest Type / Regional Ecosystem</th></tr>
<tr><td rowspan="2">BKA2
Mount Bellenden Ker south ridge</td><td>17/05/04</td><td>Estimated at 55K 377989, 8090426</td><td>1507 m</td><td>North-south trending ridgeline on steep granite mountains.</td><td>Type 10 (Simple Microphyll Vine-Fern Thicket)
RE 7.12.20</td></tr>
<tr><td colspan="5">Moderately diseased simple microphyll vine-fern thicket – unusually tall (to twenty metres).
Slender lianes, mosses and Cyathea rebeccae prominent in understorey.
Cinnamomum propinquum and Leptospermum wooroonooran prominent in canopy.</td></tr>
<tr><td rowspan="2">BKA3
Mount Bellenden Ker northern ridge</td><td>18/05/04</td><td>Estimated at 55 K 378713, 8091554</td><td>1566 m</td><td>Steep hill slope on western side of main ridgeline. Granite mountains.</td><td>Type 10 (Simple Microphyll Vine-Fern Thicket)
RE 7.12.20</td></tr>
<tr><td colspan="5">Severely diseased simple microphyll vine-fern thicket to fifteen metres.
Cyathea rebeccae and Laccospadix australasica prominent in understorey.
Cinnamomum propinquum and Elaeocarpus ferruginiflorus prominent in canopy.
Epiphytic mosses abundant.</td></tr>
<tr><td rowspan="2">BKA4
Mount Bellenden Ker northern ridge</td><td>18/05/04</td><td>Estimated at 55K 378603, 8091955</td><td>1493 m</td><td>Not recorded</td><td>Type 10 (Simple Microphyll Vine-Fern Thicket)
RE 7.12.20</td></tr>
<tr><td colspan="5">Moderately diseased simple microphyll fern-vine thicket.
Uromyrtus metrosideros, Myrsine oreophila, Elaeocarpus ferruginiflorus and Pouteria singuliflora prominent in canopy.
Dracophyllum sayeri, Gahnia sieberiana and Cyathea robertsiana present in understorey.</td></tr>
<tr><td rowspan="2">BKA5
Mount Bellenden Ker western ridge</td><td>19/05/04</td><td>Estimated at 55K 377261, 8091115</td><td>1403 m</td><td>Low rise on a northwest-southeast trending ridgeline. Surrounding slopes moderately inclined.</td><td>Type 9 (Simple Microphyll Vine-Fern Forest)
RE 7.12.19</td></tr>
<tr><td colspan="5">Moderately diseased simple microphyll vine-fern forest to 25 metres.
Laccospadix australasica and Cyathea rebeccae prominent in understorey.
Canopy species mixed. Agathis atropurpurea present.</td></tr>
</table>

Table 6: Site health ratings of the Mount Bellenden Ker monitoring sites.

Site Code	Severity of Dieback	Tree Fall Damage	Site Drainage	Disturbance of Soil	Site with positive *P. cinnamomi* response
BKU1	N/A	N/A	3	4	No (Tower Site)
BKU2	N/A	N/A	3	4	Yes (Tower Site)
BKU3	N/A	N/A	3	4	No (Tower Site)
BKU4	0	1	2	1	No
BKU5	0	1	3	1	No
BKU6	N/A	N/A	1 (in part), 2	4	Yes (Tower Site)
BKA1	3	3	3	2	No
BKA2	2	2	2	1	Yes
BKA3	3	2	3	2	No
BKA4	2	3	3	1	No
BKA5	2	2	3	1	No

Figure 3: Site BKA1. Patch death on Mount Bellenden Ker.

Figure 4: Damage to thickets of *Gahnis sieberiana* caused by pigs near Site BKU5, Mount Bellenden Ker.

Figure 5: Dieback-affected forest on the Mount Bartle Frere Western Access Track.

Figure 6: Site BFA1 on the Mount Bartle Frere Western Access Track. The forest floor is brightly lit due to canopy thinning.

3.2 TREE HEALTH ASSESSMENTS

3.2.1 Mount Bartle Frere

Study sites on Mount Bartle Frere were established in such a way that data derived could be interpreted both as site data and as transect data. Transects were eighty metres in length, comprising eight 10m x 10m plots that were centred on the access track. Table 7 indicates the mean tree health for each plot along the three transects. Mean tree health for the affected transects is at its highest (i.e. tree canopies were most open) at the centre of each transect (plots 4 and 5) and declines with distance from the track. The unaffected transect, although containing symptomatic trees, had a relatively uniform mean tree health along its length.

Changes in mean tree health over time, particularly an increase in mean tree health in plots at the ends of each transect, will indicate an increase in size of the patch death sites on the Mount Bartle Frere Western Access track.

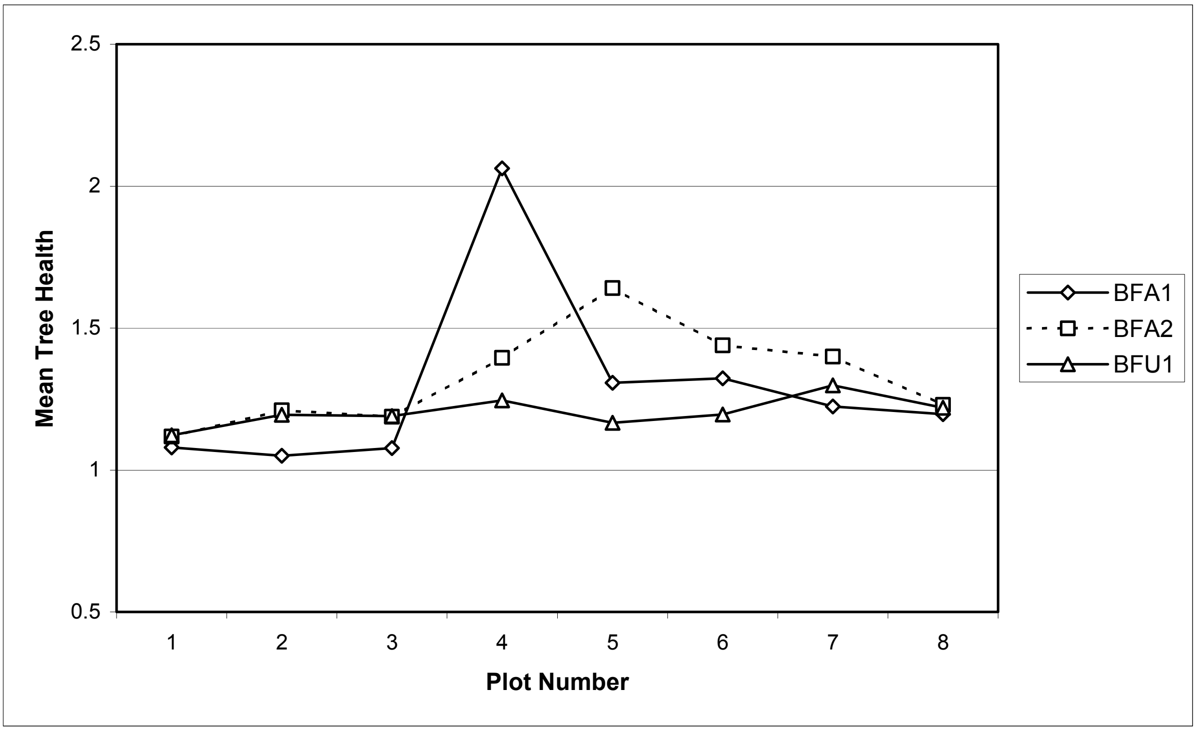

Figure 7: Mean tree health along transects at the Mount Bartle Frere study sites.

Monitoring sites on Mount Bartle Frere were notable for the high disease ratings given to one species, *Cinnamomum propinquum.* Twenty-four stems of this species were assessed during surveys – five of these were noted as *healthy*, while nine stems were rated as *recently dead*. Symptomatic trees were also observed at the site chosen as 'Unaffected'. The presence of symptomatic *C. propinquum* trees was further noted in areas outside the monitoring plots along the walking track. No investigations were conducted in areas greater than fifty metres from the Mount Bartle Frere Western Access Track. The health status of trees along the track may indicate recent infections. Species noted as field susceptible are listed in Table 7. Their mean health is given in Figure 7. Species noted as consistently healthy at all sites were *Cyathea rebeccae, Psychotria* sp. (Danbulla S. T. Blake 15262), *Balanops australiana*, *Laccospadix australasica* and *Lenwebbia lasioclada.*

Table 7: List of field susceptible tree species from the Mount Bartle Frere monitoring sites. Field susceptible species were arbitrarily chosen as those species with ≥ five stems, with two or more of those stems showing symptoms of dieback. Refer to Section 2.4.4 for tree health definitions.

Araliaceae	*Polyscias bellendenkerensis*	Myrtaceae	*Syzygium apodophyllum*
Celastraceae	*Hypsophila halleyana*	Myrtaceae	*Syzygium fratris*
Elaeocarpaceae	*Elaeocarpus ferruginiflorus*	Myrtaceae	*Syzygium johnsonii*
Euphorbiaceae	*Rockinghamia brevipes*	Myrtaceae	*Syzygium wesa*
Gentianaceae	*Fagraea fagraeacea*	Proteaceae	*Carnarvonia araliifolia* var. *montana*
Grossulariacea	*Polyosma rigidiusculae*	Proteaceae	*Musgravea stenostachya*
Lauraceae	*Cinnamomum propinquum*	Proteaceae	*Triunia montana*
Lauraceae	*Cryptocarya corrugata*	Rutaceae	*Flindersia pimenteliana* f. *oppositifolia*
Lauraceae	*Litsea connorsii*	Sapindaceae	*Mischocarpus pyriformis* ssp. *Pyriformis*
Monimiaceae	*Steganthera macooraia*	Sapindaceae	*Sarcotoechia cuneata*
Myrsinaceae	*Myrsine oreophila*	Sapotaceae	*Pouteria singuliflora*
Myrtaceae	*Rhodamnia blairiana*	Sterculiaceae	*Argyrodendron* sp. (Karnak P. I. Forster + PIF 10711)
		Symplocaceae	*Symplocos cochinchinensis* var. *glaberrima*

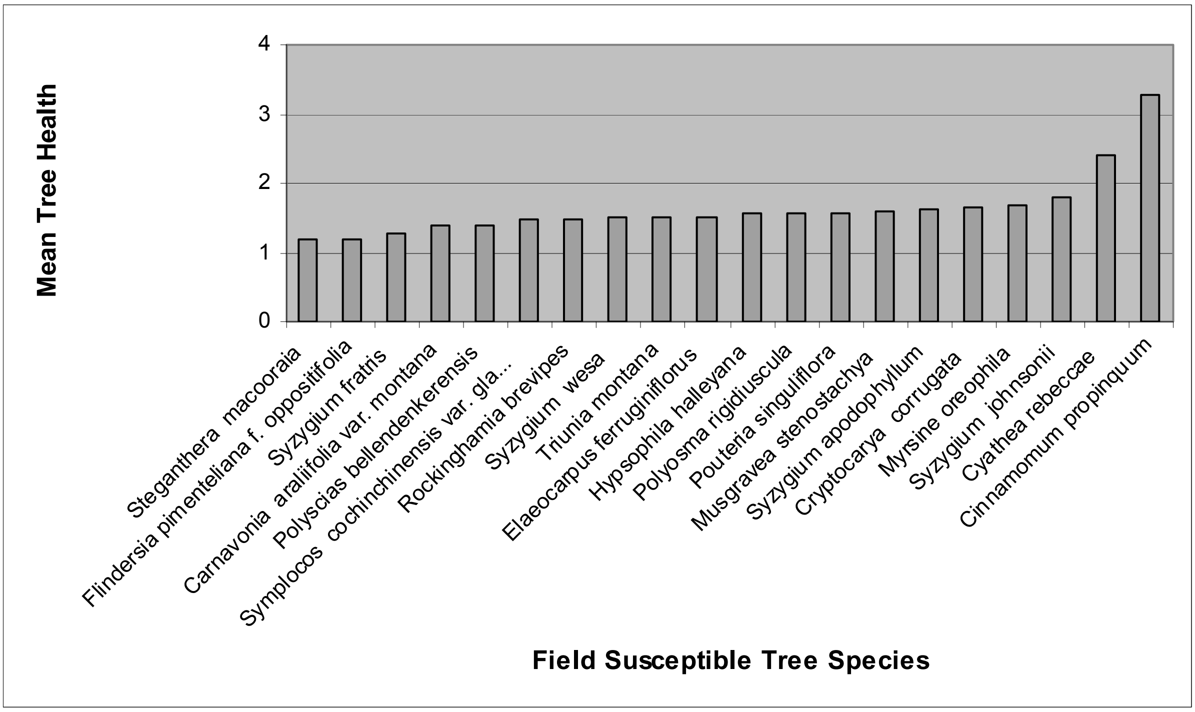

Figure 8: Mean tree health for field susceptible tree species at the Mount Bartle Frere monitoring sites. Field susceptible species were arbitrarily chosen as those species with ≥ five stems, with two or more of those stems showing symptoms of dieback. Mean tree health scale definitions are provided in Section 2.4.4.

3.3 FLORISTIC AND CANOPY COMPOSITION

Floristic composition was fully assessed at the monitoring sites established on Mount Bartle Frere and study sites on Mount Bellenden Ker. The following section summarises outcomes of these assessments. Detailed assessments for other sites are published in Gadek and Worboys (2003).

3.3.1 Species Diversity

An indication of the species diversity present at each of the Mount Bartle Frere monitoring sites is given in Figure 9. Species diversity is low compared to sites previously assessed (Gadek and Worboys 2003). The sites have a high degree of similarity, with thirty species out of the total 53 species recorded occurring at all three sites. By far the most abundant species was the understorey tree, *Rockinghamia brevipes*, with 240 stems noted in the 2,400 square metre area surveyed.

3.3.2 Successional Status

The Mount Bartle Frere monitoring sites contained no early successional or pioneer species (Figure 10). The majority of stems were identified as species typical of well-developed or undisturbed rainforests. The high proportion of class 3 and 4 species indicates a forest with little disturbance or invasion of weedy pioneers.

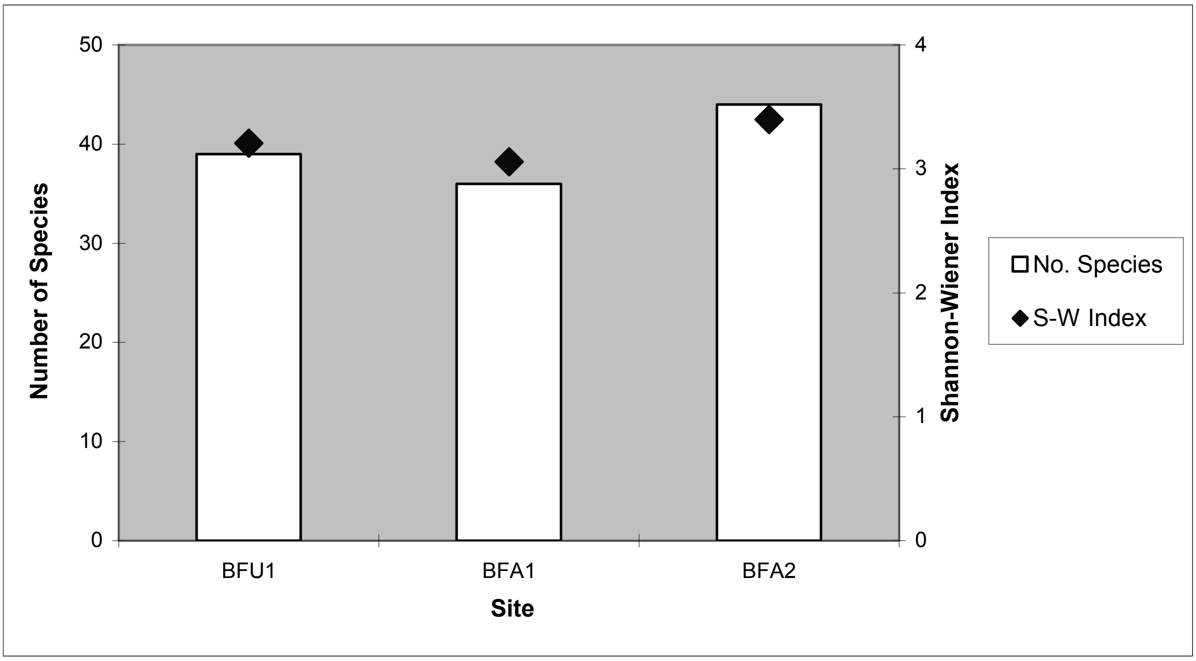

Figure 9: Species diversity at each Mount Bartle Frere monitoring site, showing the number of species present in assessments and the Shannon-Wiener Diversity Index.

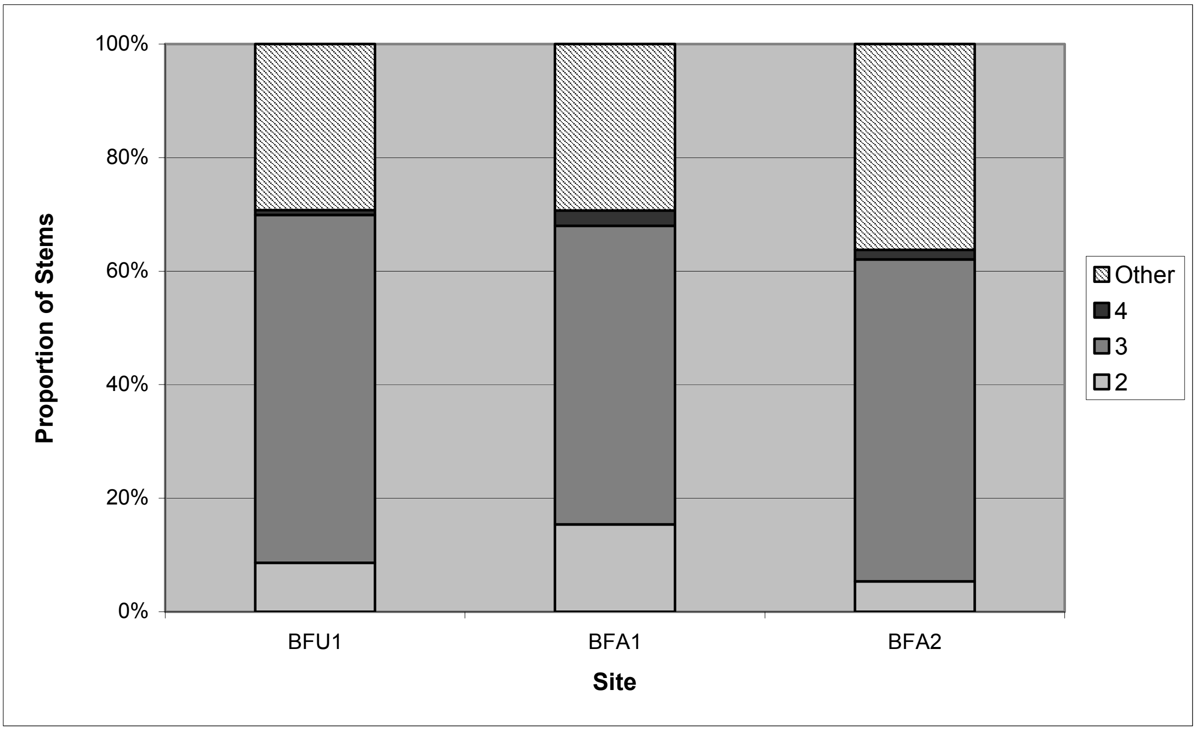

Figure 10: Proportion of stems at each Mount Bartle Frere monitoring site in each successional status category. Successional status definitions are provided in Section 2.5.3.

3.4 FERAL PIGS IN MOUNTAINTOP ENVIRONMENTS

Damage caused by feral pigs was evident at both the Mount Bartle Frere and Mount Bellenden Ker sites, occurring along walking tracks. In the few places where our inspections departed from clearly flagged and trampled walking tracks (i.e. on Mount Bellenden Ker), no pig damage was observed. Evidence of the presence of feral pigs included:

- Several areas of trampled and uprooted *Gahnia sieberiana* (Figure 4) on both the Mount Bartle Frere Western Access Track and the western ridgeline of Mount Bellenden Ker;
- A 'nest' amongst dense microphyll vine-fern thicket vegetation on the Mount Bellenden Ker eastern access track; and
- Distinctive dung on the western ridgeline track of Mount Bellenden Ker, near site BKU5 (Figure 2).

No animals were sighted during field investigations.

4. RESULTS – ALL SITES

Detailed site descriptions were published in Gadek and Worboys (2003) for the following sites:

- Tully Falls / Koombooloomba Area: CO01, CO02, CO03, ,CO04. CO05, CO06, PO01, PO02, PO03, PO04, JP04, PO05 and PO06.
- Mount Lewis Area: MLU1, MLU4, MLU6, MLA1, MLA2, MLA4, MLA5 (= MLA4b), MLA6 and MLA14.
- Kirrama / Cardwell Range Area: KIU1, KIA1, KIA2.
- Lamb Range Area: LRU1, LRA1, LRA2.

4.1 SOIL TESTING

Table 8 summarises the results of soil tests for the presence of *Phytophthora* spp. by Grow Help Australia. Two sets of results are presented; the first preliminary results provided an indication of the presence of members of the genus *Phytophthora* in the soils, whilst the second set of results provided visual confirmation of these results. Where tests detected *Phytophthora*, Grow Help Australia noted:

> "*Sporangia have now been [sighted] for all of these isolates and they have been confirmed as Phytophthora species. The isolates appeared to have very similar characteristics and may all be the same species. Most, if not all isolates, had the following characteristics: distinct (coralloid?) hyphal swellings, botryose (grape-like clusters) of chlamydospores / hyphal swellings. Sporangia were generally ellipsoid or ovoid in shape; they were persistent non-papillate and proliferated both internally and externally.*"

These physical characteristics are consistent with those recorded for *Phytophthora cinnamomi* (Stamps *et al.* 1990).

Of the 27 sites tested, eight yielded *Phytophthora* species with physical characteristics similar to *Phytophthora cinnamomi.* Two other sites (PO06 and LRA1) yielded results that indicated the possibility of contaminated isolates (i.e. when the decayed lupin roots were tested at least two different organisms emerged).

Note that no soil samples from the Koombooloomba / Tully Falls area or the Lamb Range Area gave an definite positive result for *P. cinnamomi.* Studies in the southern states of Australia have shown *P. cinnamomi* may fall below detectable levels in periods of drought or absence of susceptible hosts (e.g. Weste *et al.* 2002), however all Mount Bartle Frere sites tested positive, as did the three sites on Mount Bellenden Ker. The positive isolations on Mount Bellenden Ker were obtained from the telecommunications station site (BKU6), the foot of the first tower on the cableway (BKU2) and at an isolated dieback-affected site on the ridgeline south of the telecommunications site (BKA2).

Table 8: Results of soil testing provided by Grow Help Australia.

Study Site		***Phytophthora* reported:**	***Phytophthora cinnamomi* visually confirmed:**
Koombooloomba / Tully Falls	CO03	Not present	Not present
	CO04	Not present	Not present
	PO03	Not tested	Not tested
	PO05	Not tested	Not tested
	PO06	Confirmed	Uncertain
	JP04 (Pilot Study Site)	Not present	Not present
Lamb Range	LRU1	Not present	Not present
	LRA1	Confirmed	Uncertain
	LRA2	Uncertain	Not present
Mount Lewis	MLU6	Not present	Not present
	MLA1	Not present	Not present
	MLA4b	Confirmed	Confirmed
	MLA14	Confirmed	Confirmed
Mount Bartle Frere	BFU1	Confirmed	Confirmed
	BFA1	Confirmed	Confirmed
	BFA2	Confirmed	Confirmed
Mount Bellenden Ker	BKU1	Not present	Not present
	BKU2	Confirmed	Confirmed
	BKU3	Not present	Not present
	BKU4	Not present	Not present
	BKU5	Not present	Not present
	BKU6	Confirmed	Confirmed
	BKA1	Not present	Not present
	BKA2	Confirmed	Confirmed
	BKA3	Not present	Not present
	BKA4	Not present	Not present
	BKA5	Not present	Not present

4.2 TREE HEALTH ASSESSMENTS

Figure 11 indicates slight but consistent differences between the mean tree health in affected and unaffected sites for 2004 data. The higher the mean health (see tree health scale, Section 2.4.4), the greater the expression of disease recorded from a site. These differences are significant (ANOVA: $F_{1,\ 14} = 12.37$, $P < 0.01$).

The trends observed in 2004 reflect those observed in 2002, i.e. a higher mean tree health in affected sites, compared to unaffected sites. It is important to note that the 2002 data is presented in Figure 11 as a guide only, as no true comparisons can be made due to differing data collection methodology.

4.3 FLORISTIC AND CANOPY COMPOSITION

Floristic composition was assessed at monitoring sites established on Mount Bartle Frere and study sites on Mount Bellenden Ker. For other sites, although tree species were identified when possible, almost half of the stems (2,032) could not be confidently identified and were recorded as 'Unknown'.

Across all of the study sites:

- A total of 4,521 canopy, subcanopy and understorey trees were assessed; and
- Of the total number of trees assessed, 1,253 stems were located on unaffected sites with 157 species in 42 families recorded. Twenty new species were added to the list compiled by Worboys and Gadek (2003); these were primarily species of highland rainforests.

In terms of abundance, by far the most common species was *Rockinghamia brevipes*, a highland understorey forest species, of which 240 stems where counted. This species was not reported in Worboys and Gadek (2003).

The next most common species were *Caldcluvia australiensis* (193 stems), *Steganthera macooraia* (178 stems), the tree fern *Cyathea rebeccae* (114 stems) and *Pouteria singuliflora* (74 stems). Twenty-seven species were encountered only once. A full species list is given in Appendix 1.

4.3.1 Stem Densities

There were significant differences in mean living stem densities between affected and unaffected sites (ANOVA: $F_{1,\ 14} = 5.34$, $P < 0.05$). There was a trend for a greater density of living stems at affected sites than at unaffected sites (Figure 12). Despite this, there was no significant difference between affected and unaffected sites in the mean basal area of living stems (ANOVA: $F_{1,\ 14} = 4.15$, $P = 0.06$).

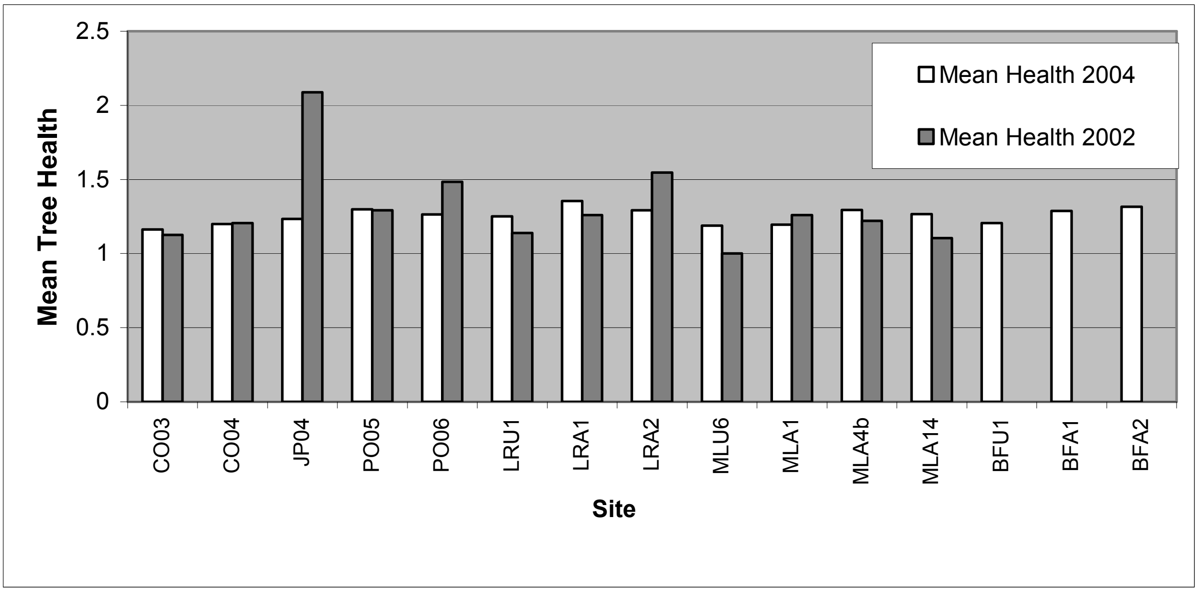

Figure 11: Mean tree health for all monitoring sites based on both the 2002 and 2004 data. Mean health was calculated using data from the same monitoring plots.

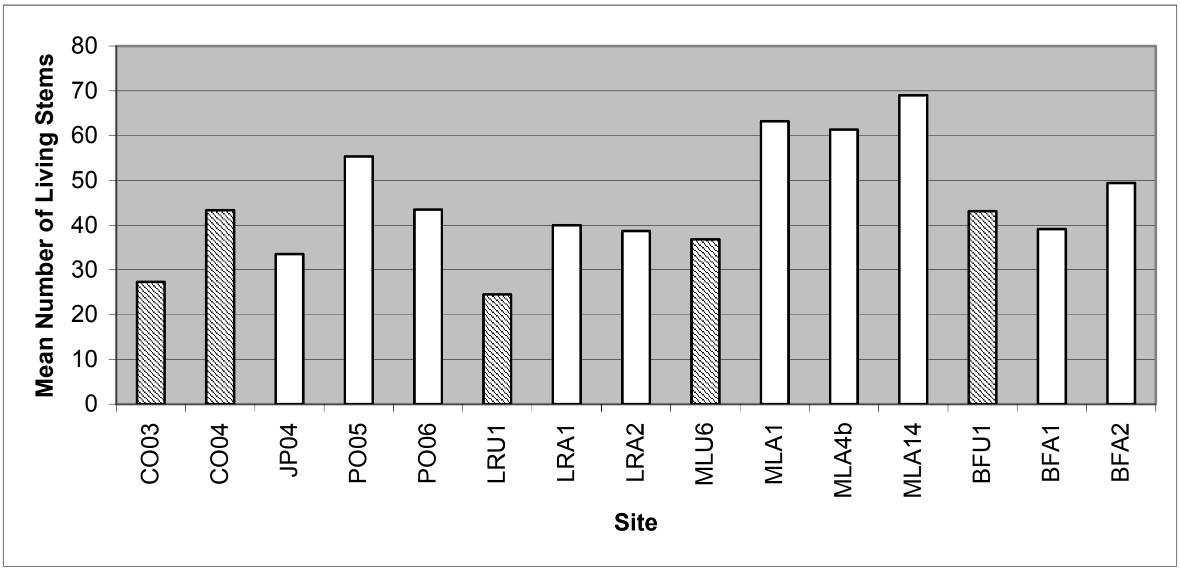

Figure 12: Mean number of living stems per plot at each study site, where each study site comprises six to eight 10m x 10m plots. Unaffected sites are hatched.

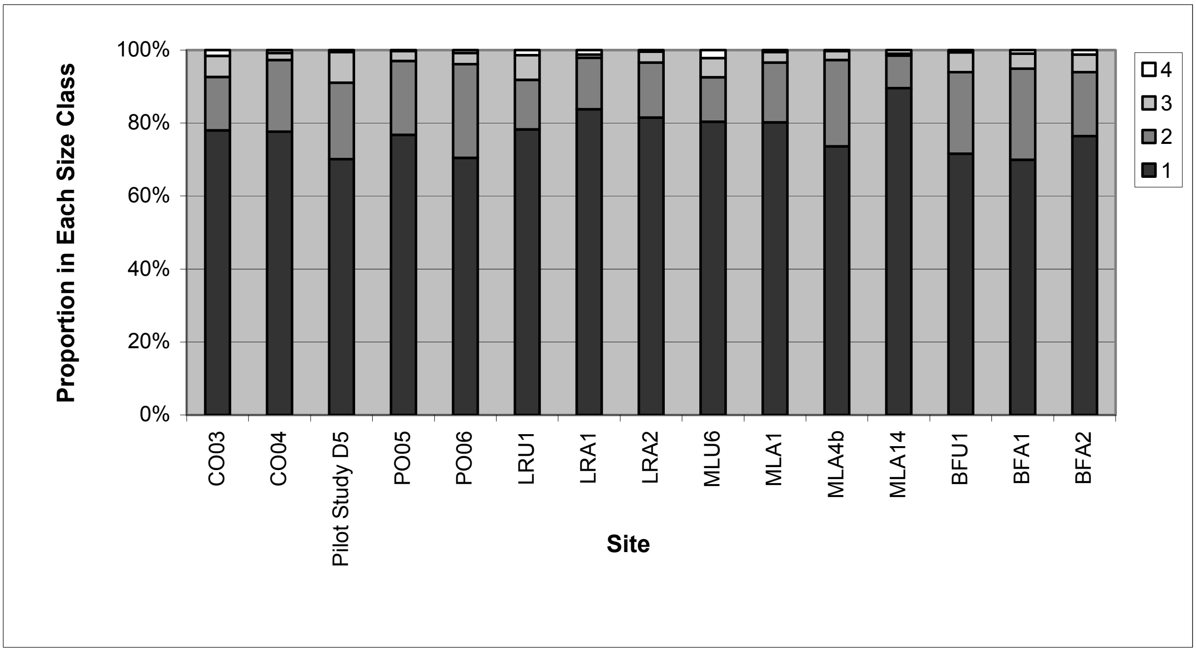

Figure 13: Proportion of stems in each size class at each monitoring site. Size class categories are provided in Section 2.4.5.

4.3.2 Rare and Threatened Species

Of the 157 species recorded across all sites, eleven were listed as *threatened* under Queensland State and/or Commonwealth legislation (Table 9). Most were new records (i.e. the rare species had not been recorded at a particular study site in previous surveys), despite less detailed floristic assessments being carried out in the 2004 surveys.

Two of the species, *Flindersia pimenteliana* var. *oppositifolia* and *Cinnamomum propinquum*, were common canopy species at the Mount Bartle Frere monitoring sites. Between them, these two species made up 4.4% of all stems in the Mount Bartle Frere sites. As noted previously, most stems of *C. propinquum* were observed to be suffering symptoms of dieback. The average health of the 24 stems assessed was 2.8, which compares with an average health of 2.0 for *Elaeocarpus sericopetalus*, the most consistently unhealthy species assessed across all sites in the 2002 surveys (Worboys and Gadek 2003).

Of the other species, the survey found the following species to be suffering symptoms of dieback:

- Five stems of *F. pimenteliana* var. *oppositifolia*;
- Three stems of *Polyscias bellendenkerensis*;
- Two stems of *Symplocos ampulliformis*; and
- One stem each of *Aceratium ferrugineum*, *Diospyros* sp. (Mount Lewis L. S. Smith 10107) and *Aglaia brassii*.

Aceratium ferrugineum was the only threatened species apart from *C. propinquum* to be reported with significant canopy thinning.

Table 9: Listed threatened species recorded at the monitoring sites. Conservation status is given, as defined in Queensland and Commonwealth legislation (V – Vulnerable; R – Rare). Species that were not previously recorded for a particular site are shaded.

Family	**Species**	**Conservation Status**	**Recorded at sites**
Araliaceae	*Polyscias bellendenkerensis*	V (Cth); R (Qld)	BFU1, BFA2
Ebenaceae	*Diospyros* sp. (Mount Lewis L. S. Smith 10107)	R (Qld)	MLA1
Elaeocarpaceae	*Aceratium ferrugineum*	R (Qld)	MLA4b
Gesneriaceae	*Lenbrassia australiana var. australiana*	R (Qld)	MLA4B
Lauraceae	*Cinnamomum propinquum*	R (Qld)	BFU1, BFA1, BFA2
Meliaceae	*Aglaia brassii*	R (Qld)	MLA1, MLU6
Proteaceae	*Eidothea zoexylocarya*	R (Qld)	BFU1
Proteaceae	*Helicia lamingtoniana*	R (Qld)	LRA1
Rutaceae	*Flindersia pimenteliana* f. *oppositifolia*	R (Qld)	BFU1, BFA1, BFA2
Symplocaceae	*Symplocos ampulliformis*	R (Qld)	BFA2
Symplocaceae	*Symplocos crassiramifera*	R (Qld)	MLA1

4.3.3 Threatened Ecosystems

Monitoring sites established on Mount Bartle Frere and the study sites assessed on Mount Bellenden Ker were all located within areas mapped as RE 7.12.19 and RE 7.12.20. Both of these are currently listed as 'Not of Concern' in the Queensland *Vegetation Management Regulation 2000*[2].

[2] As in force 1 July 2004.

5. DISCUSSION

5.1 MODIFICATIONS TO MONITORING PROTOCOL

The methodology employed in the 2002 monitoring surveys was aimed at correlating on-ground tree health observations with remote sensing data. Consequently, the 2002 monitoring surveys focussed on canopy trees visible from the centre of each 10m x 10m monitoring plot. In contrast, the 2004 monitoring procedure was simplified and focussed on the assessment of all trees within each plot. Because of this change in methodology, direct comparisons between the complete 2002 and 2004 datasets were not possible.

Despite this, it is recommended that any future monitoring be undertaken utilising the monitoring procedure outlined in this document and detailed in Worboys 2006.

5.2 MODIFICATIONS TO ZONING CRITERIA

Worboys and Gadek (2004) introduced protocols for determining dieback susceptible areas in the Wet Tropics. The criteria they prescribed were based on an analysis of the Stanton and Stanton mapping presented in Gadek *et al.* (2001).

The results presented in this document indicate there are dieback susceptible vegetation communities above 1,050 metres. Soils infested with *Phytophthora cinnamomi* were collected from dieback-affected sites on both Mount Bellenden Ker and Mount Bartle Frere.

Based on these observations and the confirmation of *P. cinnamomi* associated with severe dieback, it is recommended that the criteria for high susceptibility zones be modified to include areas above 1,050 metres altitude. Specifically, the modified criteria will state:

High susceptibility zones:

- Notophylls or microphylls dominant;
- Altitude greater than 750 metres; and
- Located on soils derived from acid igneous rocks.

As noted in Gadek and Worboys (2003), the site characteristics identified for high susceptibility zones are applicable at the broad scale and are designed for landscape-scale decision making. They insufficiently describe site-level physical characteristics.

5.3 IMPACTS ON THREATENED SPECIES AND COMMUNITIES

5.3.1 Threatened Ecological Communities

No monitoring sites were established in currently listed ‘Of Concern’ or ‘Endangered’ vegetation communities, therefore the impact of *Phytophthora*-related dieback in these communities has not been assessed. However, such a threat assessment could be undertaken through:

1. Identification of which of these communities falls within ‘high susceptibility zones’; and
2. Use of existing flora surveys to determine if susceptible species contribute substantially to the canopy in these areas.

Currently, several Regional Ecosystems are listed as 'Of Concern'[3] and are mapped in upland areas on acid-igneous rocks:

- RE 7.12.8 – Complex notophyll vine forest with emergent bunya pine (*Araucaria bidwillii*) on moist granite uplands on yellow podzolic soils.
- RE 7.12.11 – Notophyll semi-evergreen vine forest on moist to dry granite foothills and uplands.
- RE 7.12.13 – Notophyll vine forest dominated by blackwood (*Acacia melanoxylon*) on cloudy wet granite and rhyolite uplands.
- RE 7.12.17 – Simple notophyll vine forest with cadaghi (*Corymbia torelliana*) emergents on moist granite and rhyolite foothills and upland areas.
- RE 7.12.21 – Tall open rose gum (*Eucalyptus grandis*) forest on cloudy moist granite and rhyolite uplands and highlands.

The last of these communities (RE 7.12.21), although not a notophyll-dominated community, has been observed with dieback symptoms in a number of areas. This issue was discussed in detail in Gadek and Worboys (2003).

5.3.2 Threatened Species

The health of some tree species in high altitude forests was of interest. Already highlighted is *Cinnamomum propinquum*, a common highland canopy species which, on average, exhibited more severe dieback symptoms than any other species previously assessed in this project (Figure 8).

Two other rare species, *Flindersia pimenteliana* var. *oppositifolia* and *Syzygium fratris* – the former a rare variety, the latter not formally listed as *threatened* but restricted to highland forests on Mount Bartle Frere (Craven 2003) – were recorded with a number of dieback-affected stems. The restricted distribution of these species and their susceptibility under field conditions warrants concern.

5.4 DISTRIBUTION OF *PHYTOPHTHORA CINNAMOMI*

Positive isolations of *Phytophthora cinnamomi* were obtained from Mounts Lewis, Bartle Frere and Bellenden Ker. With the exception of one, all positive isolations were obtained from sites close to walking tracks or abandoned snig tracks. The exception, site BKA2, was located on a ridgeline to the south of the Mount Bellenden Ker telecommunications facility.

P. cinnamomi was isolated less often during the 2004 study than in the 2002 monitoring event. In 2002, the pathogen was identified at most of the sites sampled (Gadek and Worboys 2003). Identification was confirmed through use of molecular techniques. The differences could be due to one or more factors:

- Decline in *P. cinnamomi* inoculum at the sites, related to climatic factors (drought) or the decline of susceptible host densities;
- Issues associated with transport of the samples to Brisbane, such as extreme temperatures or unreasonable delays between sampling and commencement of the soil baiting procedure; and/or
- Utilisation of a different isolation methodology.

[3] As defined in the *Vegetation Management Regulation (2000)*, reprint 2F.

To determine if *P. cinnamomi* populations are declining or undergoing natural fluctuations, sampling must continue as an integral part of the monitoring program. Changes in soil pathogen levels could be correlated with changes in plant populations and tree health.

Pryce *et al.* (2002) have demonstrated the need for three to four samples to be taken from a site and tested independently in order to confidently determine the presence or absence of *P. cinnamomi.* Therefore, it is recommended that the soil-sampling program be maintained and that up to five samples be tested from each site. The costs and logistics of having soils tested must be discussed with Grow Help Australia (or another suitable testing agency) prior to the commencement of the project.

Previously, soil samples were collected from the centre of the site as well as points located ten metres to the north, south, east and west of the centre point. The soil sampling protocol should be altered slightly so that samples are taken from the centre of five of the plots within the site, to avoid impacting the same points year after year.

This study has confirmed the presence of *P. cinnamomi* in highland forests and its association with patch death in microphyll communities. Of particular concern was the impact on the rare endemic species, *Cinnamomum propinquum*, restricted to Mount Bartle Frere and Mount Bellenden Ker. The sensitivity of these mountaintop environments to global warming has been noted (Hilbert *et al.* 2001). Environmental stresses are frequently associated with increased susceptibility to *Phytophthora*-related dieback. It is therefore possible that decreased humidity and rainfall, together with increased temperatures associated with global warming, may increase susceptibility of *C. propinquum* and other mountaintop endemics to *Phytophthora*-related dieback. It is recommended that monitoring of the health of the Mount Bartle Frere sites be continued, with particular focus given to impacts of dieback on rare endemic species such as *C. propinquum*, *Rhododendron lochiae, Eucryphia moorei*, *Dracophyllum sayeri* and *Leucopogon malayanus.*

P. cinnamomi is present on both mountaintops and in most cases its presence is associated with human activities. Its spread is likely to be facilitated by both humans and pigs. By far the greatest proportion of humans will access these mountaintops by designated tracks and will stray little from them. However, consideration ought to be given to placing a requirement on walkers to disinfect footwear and other mud-bearing materials should they plan to deviate significantly from walking tracks. The requirement need not be onerous – a small spray bottle of methylated spirits and a brush is all that is required. The greatest difficulty will lie in educating walkers as to why this needs to be done.

6. CONCLUSION

Phytophthora cinnamomi is widespread and present in rainforests of the Wet Tropics from sea level to 1,500 metres altitude. It is associated with dieback in several places in the upland rainforests, including the high altitude rainforests of Mount Bellenden Ker and Mount Bartle Frere. Its impacts include significant thinning of canopies at affected sites, leading to the invasion of early successional species and (rarely) weeds. Affected sites show increases in stem densities. *P. cinnamomi* may pose a threat to upland rainforest ecosystems, but also to rare, restricted species that occur within them.

The following recommendations are made in addition to those given in Gadek and Worboys (2003) and Worboys and Gadek (2004):

1. Future dieback monitoring should be undertaken utilising the monitoring procedure outlined in this document and detailed in the *Guide to Monitoring* Phytophthora*-related Dieback in the Wet Tropics of North Queensland* (Worboys 2006).
2. The criteria for high susceptibility zones to be modified to include areas above 1,050 metres altitude. Specifically, the modified criteria will state:

   High susceptibility zones:

   - Notophylls or microphylls dominant;
   - Altitude greater than 750 metres; and
   - Located on soils derived from acid igneous rocks.

3. Monitoring of the health of all sites is to be continued, with particular focus given to the impacts of dieback on rare, endemic plant species occurring in high altitude forests.
4. The soil sampling program is to be continued with up to five samples being tested from each site. The costs and logistics of having soils tested must be discussed with Grow Help Australia (or another suitable testing agency) prior to the commencement of the project. The soil sampling protocol should be altered slightly so that samples are taken from the centre of five of the monitoring plots within each site to avoid measuring the same points year after year.

Two other recommendations are given here that relate specifically to activities on mountaintops. The first, the disinfecting of footwear, is not onerous and requires less than five minutes' work by individuals who carry a small brush and some methylated spirits into the field for use when cleaning. It is not anticipated this recommendation will impact on a large proportion of walkers; it can best be implemented through targeted education programs. The second recommendation arises from the isolation of *P. cinnamomi* around the telecommunications infrastructure near the peak of Mount Bellenden Ker.

5. A requirement should be placed on walkers in highland areas (specifically, Mount Bellenden Ker, Mount Bartle Frere, Carbine Tableland and Thorntons Peak) to disinfect footwear and other mud-bearing materials if they plan to deviate significantly from existing tracks.
6. All maintenance works on and around the Mount Bellenden Ker cableway should be conducted according to strict hygiene protocols, as recommended in Worboys and Gadek (2004), to limit the spread of *P. cinnamomi* from infested areas.

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8. CONTACTS AND EQUIPMENT SOURCES

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Mark Burns	Resource Ranger Assisted with field work in the Koombooloomba / Tully Falls area, and on Mount Bartle Frere, 2003 and 2004.	Lake Eacham T: (07) 4095 3768
Andrew Hedges	Resource Ranger Visited field sites in the Mount Lewis area.	Mossman T: (07) 4098 2188

Soil Analyses

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Equipment

	‘Fat chalk’ for tree marking	Harley’s Educational and Stationery Supplies 149 English Street Manunda QLD 4870 T: (07) 4053 3966
	Water resistant notebooks	Measuretek Pty Ltd 131 Scott Street Cairns QLD 4870 T: (07) 4031 5399

APPENDIX 1 – SPECIES LIST

The number of stems of each species recorded in each monitoring site is listed below. Where the number of stems was not counted, an 'x' indicates the presence of this species at the site.

		Sites												
Family	**Species**	**BFU1**	**BFA1**	**BFA2**	**BKU1**	**BKU2**	**BKU3**	**BKU4**	**BKU5**	**BKA1**	**BKA2**	**BKA3**	**BKA4**	**BKA5**
Apocynaceae	*Alyxia ilicifolia*								x					x
Apocynaceae	*Alyxia orophila*	1	3	1						x			x	
Aquifoliaceae	*Sphenostemon lobosporus*		1											
Araliaceae	*Delarbrea michieana*	1		3										
Araliaceae	*Polyscias bellendenkerensis*	2		6										
Araucariaceae	*Agathis atropurpurea*								x					x
Arecaceae	*Laccospadix australasica*	7	4	29				x	x	x				x
Arecaceae	*Linospadix microcarya*									x				x
Balanopaceae	*Balanops australiana*	2		5					x					x
Blechnaceae	*Blechnum* sp.							x						
Celastraceae	*Denhamia viridissima*	4												x
Celastraceae	*Hypsophila halleyana*	5	12	3				x		x		x	x	x
Cyatheaceae	*Cyathea rebeccae*	14	29	26				x	x	x			x	x
Cyatheaceae	*Cyathea robertsiana*												x	
Cyperaceae	*Exocarya scleroides*													x
Cyperaceae	*Gahnia sieberiana*									x			x	x
Dilleniaceae	*Hibbertia scandens*									x				
Elaeocarpaceae	*Elaeocarpus ferruginiflorus*	8	5	5			x		x	x	x	x	x	
Elaeocarpaceae	*Elaeocarpus foveolatus*			2						x				
Elaeocarpaceae	*Elaeocarpus linsmithii*		2											

		Sites												
Family	**Species**	**BFU1**	**BFA1**	**BFA2**	**BKU1**	**BKU2**	**BKU3**	**BKU4**	**BKU5**	**BKA1**	**BKA2**	**BKA3**	**BKA4**	**BKA5**
Epacridaceae	*Dracophyllum sayeri*							x				x	x	
Epacridaceae	*Trochocarpa bellendenkerensis*						x			x		x		
Euphorbiaceae	*Rockinghamia brevipes*	75	53	110										x
Gentianaceae	*Fagraea fagraeacea*	2	3	2										
Grossulariaceae	*Polyosma rigidiuscula*	14	8	18										
Grossulariaceae	*Quintinia quatrefagesii*			1										
Lauraceae	*Cinnamomum propinquum*	12	8	5					x	x	x	x		x
Lauraceae	*Cryptocarya bellendenkerana*		3	1					x	x				x
Lauraceae	*Cryptocarya corrugata*	8	5	5							x			
Lauraceae	*Litsea connorsii*		5											
Lauraceae	*Cryptocarya leucophylla*			2										
Lauraceae	*Litsea bennettii*			1			x			x	x			
Maesaceae	*Maesa haplobotrys*						x							
Monimiaceae	*Palmeria hypotephra*									x				
Monimiaceae	*Steganthera macooraia*	38	16	39				x		x		x		x
Moraceae	*Streblus glaber* var. *australianus*	1		3										
Myrsinaceae	*Myrsine oreophila*	3	10	13					x				x	
Myrsinaceae	*Rapanea achradifolia*						x			x		x		x
Myrtaceae	*Austromyrtus dallachiana*		1											
Myrtaceae	*Lenwebbia lasioclada*	12	2	4										
Myrtaceae	*Leptospermum wooroonooran*				x	x		x			x			
Myrtaceae	*Rhodamnia blairiana*	1	3	2										
Myrtaceae	*Rhodamnia sericea*									x				
Myrtaceae	*Syzygium apodophyllum*	3	4	7						x	x	x		x
Myrtaceae	*Syzygium erythrodoxum*								x					

		Sites												
Family	**Species**	**BFU1**	**BFA1**	**BFA2**	**BKU1**	**BKU2**	**BKU3**	**BKU4**	**BKU5**	**BKA1**	**BKA2**	**BKA3**	**BKA4**	**BKA5**
Myrtaceae	*Syzygium fratris*	10	18	10										
Myrtaceae	*Syzygium johnsonii*	1	4	1								x		
Myrtaceae	*Syzygium wesa*	17	13	12					x		x			x
Myrtaceae	*Uromyrtus metrosideros*	1										x	x	x
Pittosporaceae	*Pittosporum rubiginosum*			1					x					x
Proteaceae	*Carnavonia araliifolia* var. *montana*	7	5	4					x					x
Proteaceae	*Eidothea zoexylocarya*	1												
Proteaceae	*Lomatia fraxinifolia*			2										
Proteaceae	*Musgravea stenostachya*	18	17	20					x					
Proteaceae	*Orites excelsa*		2	2					x	x		x		x
Proteaceae	*Triunia montana*	2	4	4					x	x				
Rosaceae	**Rubus alceifolius*									x			x	
Rubiaceae	*Psychotria* sp. (Danbulla S. T. Blake 15262)	1	5	3					x					
Rutaceae	*Acronychia chooreechillum*	4	2	1			x		x	x	x			x
Rutaceae	*Flindersia pimenteliana* f. *oppositifolia*	11	10	3			x		x					x
Sapindaceae	*Arytera pauciflora*	1												
Sapindaceae	*Guioa montana*	1		1										
Sapindaceae	*Mischocarpus pyriformis* ssp. *pyriformis*	18	1	5					x					
Sapindaceae	*Sarcotoechia cuneata*	8	8	3								x		
Sapotaceae	*Pouteria singuliflora*	16	42	12						x	x		x	x
Solanaceae	*Solanum hamulosum*													
Smilacaceae	*Smilax glyciphylla*									x				

		Sites												
Family	**Species**	**BFU1**	**BFA1**	**BFA2**	**BKU1**	**BKU2**	**BKU3**	**BKU4**	**BKU5**	**BKA1**	**BKA2**	**BKA3**	**BKA4**	**BKA5**
Sterculiaceae	*Argyrodendron* sp. (Karnak P. I. Forster + PIF 10711)	2	2	9										
Symplocaceae	*Symplocos ampulliformis*			3										
Symplocaceae	*Symplocos cochinchinensis* var. *glaberrima*	12	8	11							x		x	
Unknown		13	13	10										
Winteraceae	*Tasmannia membranea*	2		1										
Winteraceae	*Tasmannia* sp. (Mount Bellenden KerJ.R. Clarkson 6571)						x	x						
Xanthorrhoeaceae	*Romnalda grallata*								x					