RAINFOREST RECRUITMENT AND MORTALITY IN EUCALYPT FORESTS OF THE WET TROPICS – REFINING THE MODEL FOR BETTER MANAGEMENT

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Abstract

Rainforest expansion into eucalypt forests in the wet tropics is thought to cause the localized elimination of grassy forest fauna and flora. We used data collected before and after fires, from repeat surveys of monitoring plots spanning a decade, and post wildfire observations to test the following five predictions about rainforest plant establishment and mortality within eucalypt forests:

1. rainforest plants survive infrequent, low intensity fires by vegetatively resprouting;
2. high fire frequency kills most rainforest plants;
3. a single high intensity fire kills most rainforest plants;
4. rainforest seedlings germinate continuously throughout fire intervals;
5. rainforest canopy closure eliminates grassy fuels.

Many rainforest plants are capable of surviving frequent moderate intensity fire, some multiplying their stem density as a result of regular burning. We found no evidence that an infrequent high intensity fire kills rainforest plants. However, the restriction of rainforest plants to coppicing from ground level, rather than resprouting from branches, is a critical difference compared with sclerophyll trees and means that coppicing rainforest plants remain hidden amongst the grass layer during the first few years following fire. Burning can increase the rate of rainforest establishment, through enhanced seed germination and root suckering. As the rainforest seedlings and suckers grow, the increasing subcanopy cover shades out grasses, reducing the chance of follow up intense fires.

Our data provide supporting evidence for the prediction that rainforest biomass increases with long fire intervals. However, this increase in rainforest biomass is not driven by evenly spaced germination in the absence of fire, at least not during the first decade post fire. The increase in stem density primarily occurs initially after fire as a result of fire-promoted germination and stem suckering. The increase in rainforest biomass is due to the growth in height of rainforest seedlings and suckers during intervals between fires.

As occasional high intensity fires are unlikely to remove many rainforest plants, a fire interval of five years or less seems to be required if the management objective is to maintain an open structured eucalypt forest with a moderately dense grass layer. If dense rainforest seed germination occurs after a fire, then it may be appropriate to implement a follow up fire in the following year to thin those seedlings out before they develop the capacity to become established.

Keywords: wet sclerophyll forest; fire, rainforest regeneration

Introduction

The increased density of rainforest plants within eucalypt forests in the wet tropics of north eastern Australia is considered by some ecologists to be of concern, due to the apparent elimination of grassy wet sclerophyll forest fauna and flora. Hopkins *et al*. (1993), Harrington (1995) and Bowman (2000) each produced a similar general model describing rainforest expansion into eucalypt forest in the wet tropics (Figure 1). This model proposes that after about five years without fire, small rainforest plants will have recruited under the eucalypt side of the rainforest-eucalypt forest ecotone and the grasses will have thinned. A low intensity fire at this five year stage is predicted to kill rainforest plants that had established underneath the eucalypts, but not affect the rainforest side of the boundary. A high intensity fire at this stage (five years after a previous fire) will kill all rainforest plants under the eucalypt forest, as well as kill rainforest plants on the rainforest side of the ecotone and also push eucalypt forest plants into the previously rainforest side of the boundary. The absence of fire for 30 years will lead to a canopy of mature rainforest plants under eucalypt emergents and all eucalypts will have disappeared by 100 years when it is then pure rainforest.

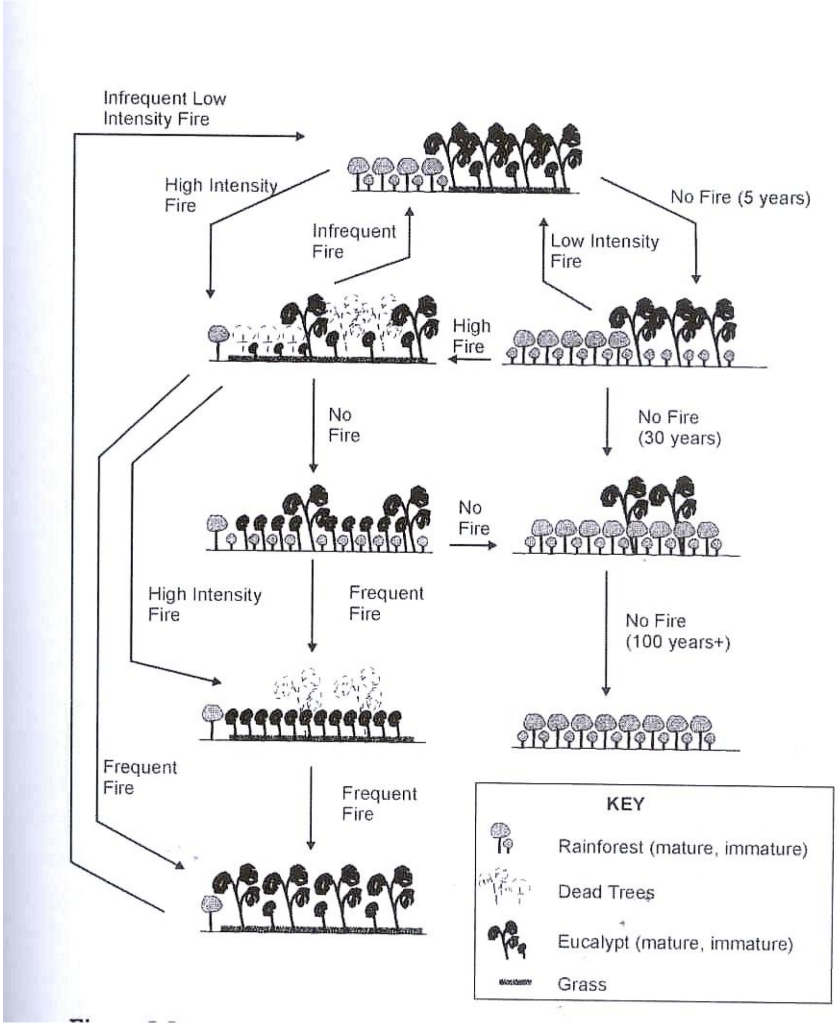

Figure 1. General model of rainforest establishment and mortality in relation to fire regime in eucalypt forests in the wet tropics. From Bowman (2000) page 163, adapted from Harrington (1995) and Hopkins *et al*. (1993).

In his thorough review of fire and rainforest distribution, Bowman (2000) predicted that the critical factor governing rainforest distribution in the humid tropics is the “periodicity and intensity of fire”. He articulated the mechanisms driving this tropical humid rainforest-eucalypt boundary dynamics model as follows:

1. rainforest plants are relatively resistant to mild fires (i.e. they vegetatively resprout after low intensity fires);
2. rainforest is most likely to retreat if fires occur with high frequency due to a high grass biomass (i.e. high fire frequency kills rainforest plants);
3. a single high intensity fire can cause rapid retreat of rainforest when extreme climatic events such as frosts, droughts and cyclones produce large accumulations of dry fuels (i.e. a single high intensity fire kills rainforest plants);
4. in the absence of fire, rainforest seedlings can invade non-rainforest vegetation (i.e. continuous rainforest seed germination through fire intervals);
5. once the invading rainforest has achieved canopy closure, the consequent elimination of grassy fuels decreases the risk of fire, which in turn favours long-term establishment of rainforest (i.e. rainforest canopy cover shades out grasses, reducing the chance of further fires).

This paper uses data collected from repeat surveys, before and after fires, of permanently marked plots in the wet tropics to evaluate Bowman's (2000) specific predictions and the general model of Hopkins *et al*. 1993; Harrington 1995 and Bowman 2000. Specifically it addresses five hypotheses:

1. rainforest plants vegetatively resprout after infrequent low intensity fires;
2. high fire frequency kills most rainforest plants;
3. a single high intensity fire kills most rainforest plants;
4. continuous rainforest seed germination through fire intervals;
5. rainforest canopy closure eliminates grassy fuels.

Methods

Data were collected from several locations in the Townsville to Cardwell southern region of the wet tropics: Herkes Creek, Wallaman Falls, Mt Fox and Paluma. At each location, plots were marked out permanently using metal pickets to allow the repeat surveys in the exact location. All plots were 100 m^2, either 10 m X 10 m, or 25 m X 4 m in size. The number of woody plants were recorded within each plot during each survey. Nineteen separate plots were surveyed a total of 57 times over the ten years. There were a total of 20 plot fires (i.e. the number of times a plot was burnt), although not all plots were surveyed after every fire that passed through them.

Following drought conditions, an unusually high intensity fire burnt through *Eucalyptus grandis* forest with rainforest understorey along the Taravale road, west of Paluma. This fire scorched the upper canopy of the 30 m tall *Eucalyptus grandis* forest and was the highest intensity recalled by staff in the region. While we can't claim this to be the highest intensity fire possible in the area, this fire represents our best opportunity in recent years to test the effects of a high intensity fire on rainforest regeneration. We did not quantitatively document rainforest density prior to the Taravale road fire. However, the authors walked through sections of the forest only a few months prior to the fire, whilst undertaking a small mammal survey through the area. Rainforest density varied across several kilometres, being high in many sections, so that it difficult to transverse and with no grass cover, but with some areas having only moderate rainforest density with some grass cover. Photos were taken immediately following the 2003 high intensity Paluma fire, with subsequent photos at the same points taken periodically.

Results

Hypothesis 1: rainforest plants vegetatively resprout after infrequent low intensity fires.
Infrequent low to moderate intensity fires at various sites across the southern Wet Tropics did not kill many rainforest plants. While one species, *Alphitonia petrei*, is a fire-killed tree with fire promoted germination, other rainforest trees, shrubs and vines regrew vegetatively from buds located at the stem base or along roots. Some rainforest species increased stem density as a result of root suckering (e.g. *Alstonia muelleriana*).

Hypothesis 2: high fire frequency kills rainforest plants.
Low to moderate intensity fires at Wallaman Falls, with intervals varying from one to three years producing four fires in a decade, did not kill many rainforest plants. The numbers of some rainforest species did decline after a decade of repeated fires (e.g. of *Duboisia myoporioides*) but as a group, rainforest species were just as resilient to frequent fires as sclerophyll trees (i.e. some mortality was also observed in the sclerophyll trees *Allocasuarina littoralis*, *A. torlusoa*, *Banksia integrifolia*, *Lophostemon suaveolens*).

All 28 woody rainforest plants alive after the 2003 intense wildfire, survived a subsequent low intensity fire in 2004, within a plot in the Paluma area. Therefore those rainforest plants were able to survive an intense fire followed by a low intensity fire, two years in a row.

Hypothesis 3: *high fire intensity kills rainforest plants.*
Rainforest shrubs and trees resprouted from the base of stems and along roots. The high density of post-fire resprouting rainforest plants throughout the forest indicated that an occasional high intensity fire did not remove rainforest plants from the eucalypt forest. In addition, the grass layer did not return within two years, into areas where grasses were absent prior to the fire.

Hypothesis 4: *continuous rainforest seed germination through fire intervals.*
Rather than rainforest seedlings invading into long unburnt eucalypt forests, rainforest plants germinated seedlings sporadically in our plots over the last decade, and generally in greatest abundance in the first year after fire. For

Table 1. Change in plant density with time since the November 1996 fire at Wallaman Falls. Data are combined from two 100m^2 monitoring plots.

Sclerophyll trees & shrubs	April 1997 ½ year post fire	Sept 1997 1 year post fire	April 1999 2½ years post fire	Oct 2005 9 years post fire
Acacia flavescens	11	20	10	5
Allocasuarina littoralis	2	9	2	4
Allocasuarina torulosa	19	16	7	9
Alphitonia excelsa	4	4	4	0
Banksia aquilonia	8	7	5	4
Corymbia intermedia	6	10	7	4
Corymbias torelliana	1	1	0	0
Eucalyptus tereticornis	3	3	5	3
Lantana camara	0	0	1	0
Lophostemon suaveolens	4	10	4	4
Total Sclerophyll plants	**58**	**80**	**45**	**33**
Rainforest trees & shrubs				
Acacia aulacocarpa / A. cincinnata	203	152	28	29
Alphitonia petrei	531	727	181	36
Alstonia muelleriana	64	107	72	54
Callicarpa pendunculata	3	5	3	0
Canthium sp.	3	5	2	2
Chionanthus ramiflora	0	0	0	1
Cissus opaca	1	1	0	0
Commersonia bartramiana	9	14	12	9
Cryptocarya sp.	0	0	0	2
Diospyros pentamera	7	6	3	3
Euroschinus falcata	0	0	1	6
Glochidion sp.	0	6	4	4
Guioa acutifolia	1	4	4	8
Mallotus paniculata	3	4	2	0
Melastoma affine	43	110	83	29
Melicope elleryana	4	4	14	3
Neolitsea dealbata	1	1	1	1
Polyscias australianum	0	1	3	21
Rainforest unidentified sp	0	0	0	1
Rapanea variabilis	2	1	1	2
Rhodomyrtus trineura	12	14	12	30
Trema tomentosus	145	98	21	0
Total rainforest plants	**1032**	**1260**	**447**	**241**

example, rainforest germination in the first year following fire was 71 times more dense in 1997, and 35 times more dense in 1998, than adjacent sites unburnt for at least five years in eucalypt forest at Wallaman Falls (Williams 2000). Two Wallaman Falls plots have remained unburnt for nine years following the 1996 fire. Table 1 shows how the number of plants in those plots has fluctuated over the years since fire. The highest number of plants was present in the first year after fire, and declined with further years after fire. This was due to dense seed germination and some vegetative root suckering of new stems in the first year after fire. The subsequent decline in plant density was as a result of high mortality of seedlings and some death of root-sucker stems. Only minor numbers of new seedlings established in the second to ninth year after fire (especially of *Polyscias australianum* and *Rhodomyrtus trineura*), highlighting the role of fire as a trigger for recruiting many rainforest species. However, it is possible that after about nine years post fire, that additional rainforest plants may begin recruiting into the sparse ground cover and leaf litter.

Although overall rainforest germination was limited in other areas, rainforest seedlings were consistently more abundant in the first year after fire than in later years at Herkes Creek and Paluma plots.

Hypothesis 5: *rainforest canopy closure eliminates grassy fuels.*
The Wallaman Falls plot data confirms that the absence of fire for approximately five or six years leads to a dramatic decline in blady grass (*Imperata cylindrica*) and kangaroo grass (*Themeda triandra*). In contrast, burning every two or three years promotes dense native grass cover, especially kangaroo grass.

Discussion

Hypothesis 1: rainforest plants vegetatively resprout after infrequent low intensity fires.
The concept of tropical and subtropical rainforest plants vegetatively resprouting after at least a single mild (i.e. low intensity) fire has already been well demonstrated (e.g. Stocker 1981;Williams 2000; Campbell & Clarke 2006). Data presented in this paper confirm the ability of many rainforest plants to survive an occasional low intensity fires. These data also highlight the ability of some rainforest plants to use fire to vegetatively expand their stem density.

The critical difference between rainforest and sclerophyll trees of the eucalypt forest is that when completely scorched, rainforest plants appear restricted to resprouting from subsoil buds located at the base of stems or along roots. The ability of sclerophyll forest trees (e.g. *Eucalyptus* spp., *Corymbia* spp., *Allocasuarina torulosa* and *Lophostemen suaveolens*) to epicormically resprout from trunks and branches, maintains their existing trunk height and allows rapid re-establishment of canopy and continued vertical growth. The restriction of rainforest plants to restart growth from the ground level, necessitates several years of growth to return to pre-fire height before additional height can be gained. We believe this is the critical mechanism by which frequent fire maintains an open structured forest and the appearance of low rainforest density.

Hypothesis 2: high fire frequency kills rainforest plants.
Evidence from repeat surveys from permanent plots following frequent fires (e.g. four fires in ten years) indicates that many rainforest plants are able to survive high fire frequency and in the case of *Alstonia muelleriana*, can vegetatively expand following fires. Our data indicate that some rainforest plants are capable of vegetatively surviving an intense fire, followed in the next year by a low intensity fire. However, a proportion of some rainforest species (e.g. *Dubosia myoporioides* saplings at Wallaman Falls) and sclerophyll plants (e.g. *Lophostemon suaveolens* saplings) are killed by high fire frequency, which fits the general concept that high fire frequency can reduce woody species density. In fact, rainforest plants were able to survive frequent fire better than the eucalypt forest obligate seeder *Dodonaea triquetra*.

Hypothesis 3: *high fire intensity kills rainforest plants.*
An unusually high intensity fire that burnt through eucalypt forest at Paluma in 2003 did not remove the rainforest plants, which regrew from buds at the base of the stem and along roots, nor did the grass layer return within two years, into areas which grasses were absent prior to the fire. Therefore we found no evidence to support the idea that an occasional high intensity fire would remove the rainforest from under the eucalypt forest, thus resetting the boundary. If these results from the Paluma fire are found to be consistent in other areas after future high intensity fires, then these results have important consequences for the wet sclerophyll forest model and on ground management. That is, it would appear inappropriate to rely on an occasional high intensity fire to remove rainforest plants, if the objective is to maintain areas of grassy wet sclerophyll forest with low densities of rainforest plants.

Hypothesis 4: *continuous rainforest seed germination through fire intervals.*
Our evidence indicates that while rainforest seed germination does not occur at high densities following every fire, there tends to be more seed germination in the first year following fire than two to nine years after fire. This is consistent with the initial Wallaman data (Williams 2000). Long term data from Wallaman plots, followed for nine years after fire, indicates the main recruitment event of rainforest seedlings does occur in the first year following fire, with subsequent mortality of those seedlings far outweighing the few additional seedlings germinating in later years. However, once the grass layer has disappeared, some rainforest seedlings, e.g. *Polyscias* spp., recruit amongst the leaf litter.

Hypothesis 5: *rainforest canopy closure eliminates grassy fuels.*
Data following a few plots over nine years after burning confirmed the inverse correlation between rainforest subcanopy cover and grass cover. While the decline in grass cover and increase in rainforest canopy cover both occur with increased time since fire, the rate differs between plots. The relationship of grass cover with fire interval is weaker than with rainforest canopy cover. This evidence supports the hypothesis that the decline in grass cover

with time since fire is strongly affected by, if not driven by, shading by rainforest canopy. The variation between sites with time since fire probably is a result of different densities of rainforest canopy.

Conclusion

While the broad concept that rainforest biomass in eucalypt forests increases with long fire intervals (e.g. greater than five years) is confirmed by these data; the specific aspects of rainforest recruitment and mortality hypothesized in the current model require refining.

Many rainforest plants are capable of surviving frequent moderate intensity fire, some apparently multiplying their stem density as a result of regular burning. Infrequent high intensity fire does not necessarily kill rainforest plants either. However, the restriction of rainforest plants to resprouting from ground level, rather than the capacity to resprout from branches, is a critical difference to that of the sclerophyll trees and means that coppicing rainforest plants remain hidden amongst dense grasses during the first few years following fire. We believe that this has led to the mistaken belief that fires kill all rainforest plants. The fact that it takes one or two years for the resprouting rainforest plants to grow above the grass layer, so that they are easily seen, probably has lead to the idea that rainforest plants germinate and establish a few years after fire. These data suggest fire can increase the rate of rainforest establishment, through enhanced seed germination density and via the coppicing of more stems than were present prior to a fire. As the rainforest seedlings and resprouts grow, the increasing subcanopy cover shades out grasses, reducing the chance of follow up fires, as predicted in the existing model.

Although the broader concept of rainforest increase with long fire intervals is confirmed by these data, it is important to refine our understanding of the finer details of recruitment and mortality that influence rainforest expansion. This knowledge leads to more appropriate management. For example, if rainforest plants were removed following an occasional high intensity fire, then land managers could either leave these forest types unmanaged to burn in some unspecified but inevitable wildfire or implement fires every few decades with appropriately dry weather conditions. However, the knowledge that an occasional high intensity fire does not kill many rainforest plants nor re-establish a grassy ground layer, indicates that the occasional infrequent fire regime is unlikely to maintain grassy eucalypt forests. Data from this study suggests that, depending on the existing density of rainforest plants, a fire interval of less than five years is most likely to be required if the management objective is to maintain a moderately dense grass layer and a low rainforest subcanopy height. If dense rainforest seed germination occurs after some fires, then it may be appropriate to implement a follow up fire in the following year to thin those seedlings out before they develop the capacity to become established.

Further research is required to refine our understanding of grass fuel load dynamics with respect to canopy cover and time since fire. Evaluations of the variations in fire intensities reached with different grass biomass is required. Seed germination events of rainforest plants appears to be irregular and additional observations testing the link between recruitment, fire rain and even grazing will provide a greater understanding of rainforest establishment. Determining the earliest age at which rainforest seedlings can coppice after a fire is also a crucial missing link.

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