Vegetation dynamics, fuel loads and fire in an "of concern" regional ecosystem on Magnetic Island National Park. A 25 year study: 1982 to 2007.

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Based on a re-survey and evaluation of sites established by Carolyn Sandercoe and Magnetic Island Rangers in 1982.

Summary

Plant species composition, vegetation structure and fuel load changes over the last 25 years were evaluated in a eucalypt and wattle dominated woodland on Magnetic Island. This regional ecosystem (11.12.16) has an “Of concern” status under the Queensland Vegetation Management Act (1999). An initial August 1982 vegetation survey, annual fuel load samples (from 1982 to 1993) and annual photo monitoring (1984 to 1992 in most sites), by Carolyn Sandercoe and Magnetic Island rangers, were compared with a survey in August 2007. The annual photo monitoring and fuel sampling in the 1980’s to early 1990’s allowed examinations of the rate and timing of change over the first half of the 25 year study.

The four sites which were unburnt for more than 16 years showed dramatic reductions in grass cover, including a complete loss of grass from two sites categorised in 1982 as having a “tall dense grass” fuel type. The reductions in grass cover were driven primarily by a decline in the native grasses *Cymbopogon bombycinus*, *Heteropogon triticeus* and *Themeda triandra*. Sites burnt within the last 10 years contained moderate grass cover and higher numbers of plant species than sites unburnt for at least 16 years. Several grasses and herbs were only present within the most frequently burnt sites.

The canopy of sparse dead tall eucalypts, present in 1982, was not replaced by the growth of eucalypt saplings into tall trees during the study, irrespective of fire history. The long unburnt sites were not invaded by rainforest, as occurs in some wetter eucalypt forests of the Wet Tropics. Instead, there was a loss of the ground cover element of the woodland, coupled with some thickening of small trees, especially *Acacia leptostachya*, which were present during the original 1982 survey. The woody weeds rubbervine (*Cryptostegia grandiflora*) and *Lantana camara* increased in abundance in sites which were not burnt in the last 16 years.

Even the most frequently burnt sites in this study, sites 5 and 7 burnt four times in the last 25 years, have a fire frequency lower than that recommended for mixed eucalypt-grassy woodlands on Magnetic Island and also across the region, i.e. fire intervals of 3 to 5 years. Similar woodland sites on the mainland that receive fire intervals between 2 to 4 years have higher species numbers than in the most frequently burnt sites in this study. Regular fire is clearly needed to maintain the abundance and diversity of grasses and herbs in the ground layer strata of this woodland.

The long absence of fire led to a change in fuel loads, from aerated 1.5 m tall grass fuel to a dense leaf litter and twig cover at the soil surface. This leaf litter and twig fuel load was heavier than a moderate grass load, though less than the grass-dominated fuel of these sites when more frequently burnt. The leaf litter and twigs do not appear to carry fire easily.

It is recommended that fire intervals be returned to an average of 3 to 5 years, with some areas allowed to experience longer periods without fire, to maintain the cover and diversity of grasses and herbs. Fires should primarily be implemented in the early to mid dry season, to ensure low to moderate fire intensity to reduce the risk of causing tree death.

Background
In 1982, Carolyn Sandercoe, botanist with Queensland National Parks and Wildlife Service, worked with the Magnetic Island rangers to evaluate fire management on Magnetic Island National Park.

As part of the project, fuel loads on Magnetic Island were categorised into five broad types (from Sandercoe 1989):

1. Spinifex (*Triodia stenostachya*) on coastal hills.

2. Tall dense grass, including Lemon grass (*Cymbopogon bombycinus*), black spear grass (*Heteropogon contortus*), giant spear grasss (*Heteropogon triticeus*) and cane grass (*Mnesithea rottboellioides*). This fuel type occurs on the lowlands and hills.

3. Grass on hills, occurs in areas infrequently burnt and with dense tree cover and some rock cover.

4. Grass and leaf litter at high altitude, including blady grass (*Imperata cylindrica*) grass trees (*Xanthorrhoea johnsonii*), and *Allocasuarina torulosa* leaf litter.

5. Sedge and leaf litter, especially the sedges *Scleria sphacelata* and *Gahnia aspera*. This fuel type occurs in the valleys between hills under dense tree canopies.

To document the fluctuations in fuel loads in relation to fire, Carolyn Sandercoe and the Magnetic Island rangers established nine permanent sites in 1982. Two sites were established in fuel load type 1 (spinifex), three sites in fuel load type 2 (tall dense grass) and four sites in fuel load type 3 (grass on hills). The fuel loads in these nine sites were sampled annually, from 1982 to 1993. Photos were taken of the sites annually to 1992, although for many of the sites the initial photo was taken in 1984, rather than 1982.

Sandercoe (1989) reported the results of the annual field load sampling and photo monitoring, up to 1988. These results demonstrated that fuel loads in the unburnt sites varied annually, due to rainfall and the patchiness of fuel at a small scale within each site. The “grass on hills” fuel type was considered to reach a maximum equilibrium most quickly, after about two years (see summary in Table 1). The dense grass produced a higher fuel weight than grasses on hills, but slightly slower, reaching a maximum after about 3 years. Spinifex was found to have the highest maximum fuel load (up to 15 tonnes/ha) but which requires at least 6 six to be reached.

Table 1: Summary of information in Carolyn Sandercoe's 1989 report, on fuel load recovery after fire and equilibrium weights for the five fuel load types.

Fuel type	Recovery after fire and equilibrium weight
1. Spinifex (*Triodia stenostachya*) on coastal hills	Recovery after fire is slow due to spinifex regeneration via seedlings, rather than coppice shoots. Equilibrium of fuel load was estimated to be up to 20 – 30 tonnes/ha, or up to 15 tonnes/ha if under shrubs.
2. Tall dense grass	Regeneration after fire is via resprouting suckering and seedlings. A fuel load equilibrium of up to 10 tonnes/ha accumulates within 2 to 3 years after fire.
3. Grass on hills	Fuel load equilibrium can reach up to 10 tonnes/ha, but more usually around 4 tonnes/ha. This equilibrium is rapidly reached by 2 years after fire.
4. Grass and leaf litter at high altitude	Fuel load equilibrium can reach up to 9 tonnes/ha. Grass load recovery may be rapid, but accumulation of leaf litter builds over several years.
5. Sedge and leaf litter, in the valleys between hills under dense tree canopies	Fuel load equilibrium can reach up to 2 - 7 tonnes/ha, fluctuating seasonally. Fuel load recovery may be slow after fire because of the slow accumulation of leaf litter.

In concluding, Sandercoe (1989) felt the hills behind Horseshoe Bay had been burnt too frequently by wildfires in the decades before 1982, which was thought to have changed the structure (i.e. death of canopy trees) and plant composition. She recommended reducing the frequency of fires, by implementing small fuel reduction burns in strategic lowland locations to reduce the risk of wildfires. Sandercoe (1989) felt that "there seems to be virtually no possibility that the deliberate burning in the hills would ever be necessary to maintain biological integrity".

This study

The community in which sites 1 to 7 were established has been mapped by the Queensland Herbarium as regional ecosystem 11.12.16, a mixed eucalypt and wattle woodland. This regional ecosystem has an "Of concern" status under the Queensland Vegetation Management Act (1999). In 2007, 25 years after the establishment of the fuel sites, an evaluation was made of the plant composition, structure and fuel loads at the sites established in 1982. The 2007 study aimed to evaluate whether there had been changes at the sites in regards to:

1. plant species composition;
2. vegetation structure;
3. fuel loads.

The influence of recent fire history on any changes was evaluated, so that the information could be used to refine fire management on the island.

Methods

Details on the nine permanent sites that Carolyn Sandercoe and the Magnetic Island rangers established in 1982 are provided in Table 2. Two metal star pickets were used to mark each site. Eight of the nine sites were located near each other, as pairs, differing in whether they had been burnt in 1982.

Table 2: Details of the nine fuel load sites established in 1982

Site number	Location (in WGS 1984 datum)	Fuel load type in 1982	Years burnt (since 1977)
1	484821 East 7884774 North	Tall dense grass	1977, 1987, 1991
2	484811 East 7884759 North	Tall dense grass	1982, 1987 and 1991
3	485739 East 7883680 North	Grass on hills	1977,1997
4	485816 East 7883650 North	Grass on hills	1982
5	485146 East 7883958 North	Tall dense grass	1982, 1987, 1991 and 2006
6	484903 East 7883738 North	Grass on hills	unburnt
7	484896 East 7883758 North	Grass on hills	1982, 1987, 1991 and 2006
8		Spinifex	unburnt
9		Spinifex	1982

Plant species composition

In 1982, Carolyn Sandercoe documented a list of plants, with comments on the abundance of several species, for each pair of sites. That is, a single record of plant composition was made covering both sites 1 and 2, also for sites 3 and 4, and for sites 6 and 7. An individual plant list was made in 1982 for site 5. In 2007, plant species composition was recorded for each individual site, with the % cover of grasses estimated. Although the sites contained star pickets marking the middle of the site, no specific site boundaries were marked out and sites were considered to cover a 10 m diameter around the centre star picket (this is the area used by Sandercoe 1990 for similar surveys in White Mountains National Park). Photo monitoring of sites during the 1980’s and early 1990’s (up to 1992 or 1993, depending on the site) were compared with the 2007 photos, to help visualise the original grass cover and woody plant density. The photo series also allowed an examination the rate and timing of grass cover decline.

As the original 1982 species list combined species for pairs of sites, which covered both a burnt and unburnt site in 1982, it is difficult to follow changes in individual sites between 1982 and 2007. Therefore, to evaluate the effect of fire history on species composition, the 2007 species lists for each site were compared. To see whether changes occurred consistently (i.e. repeated across more than one site) the seven sites were categorised into two broad fire history groups:

1. Sites unburnt for at least 16 years (that is the last fire being 1991 or earlier). These were sites 1, 2, 4, and 6.

2. Sites burnt within the last 10 years. These were sites 3, 5 and 7. Sites 5 and 7 also had four fires in the last 25 years, compared with two or less in other sites.

Differences in the number of species per site and percentage grass cover were subjected to a *t*-test to examine whether any differences between groups of sites with different fire histories are statistically significant. A significant *P* level was set at 0.1 rather than the more conventional 0.05. This means that there would be a 90% or more certainty that significant differences were picked up (rather than relying on a 95% or higher confidence level before concluding a significant change). This follows Field's *et al*. (2007) recommendation, who argued for increasing the *P* level slightly, because the objective of ecological monitoring is to detect any change early enough to allow changed management practices.

Vegetation structure
The 1982 vegetation structure for each site pair was documented by recording "structural density" (e.g. sparse or dense), height and species composition for vegetation layers: tall trees, trees, low tree – tall shrubs and the ground cover. Heights and abundance (numbers for trees and shrubs, % cove for grasses) were recorded in 2007, so that direct comparisons could be made with the 1982 data. Photos taken in the 1980's and early 1990's were compared with the 2007 photos, to help determine changes in vegetation structure for individual sites over time.

Fuel loads
The annual fuel load sampling methodology used from 1982 to 1993, was replicated in 2007. The method involved cutting grass and collecting leaf litter and twigs < 6mm diameter, from within a 0.5 m X 0.5m quadrat (an area of 0.25 m^2). Five 0.5 m X 0.5m quadrat samples were collected from each site annually, with the location of each quadrat sample being determined randomly, by throwing a hat in the vicinity of the star picket. Samples were dried for several days in the CSIRO Davies laboratory drying oven, set at 65° C, prior to being weighed to provide a dry weight for fuel. Each sample provided a fuel load estimate in grams per 0.25 m^2. This was converted to tonnes per hectare (t/ha) for each sample, by multiplying the sample weight by 0.04. An average t/ha weight per site for each year was calculated from the 5 sub-samples.

For sites burnt during the 1982 to 1993 sampling period, an assessment was made of the number of years before a maximum fuel load is reached after fire. To do this, only instances where a maximum fuel load and subsequent declined was reached were used (i.e. an increase in fuel load was not interrupted by a subsequent fire, or loss of records after 1993).

Results
Plant species composition
A total of 50 species were observed during the 1982 and 2007 surveys. There were more species recorded in each site pair during 2007 than in 1982, with an average of 17 species per site pair recorded in 2007 and 9 in 1982. Part of the reason for a lower number of plant species recorded in 1982, was that one site in each site pair recording had been burnt only a month prior to surveying and hence many of herbs would not have germinated or have been too small to identify (i.e. sites 2, 4, 5 and 7).

The species that disappeared from at least one site pair between 1982 and 2007 were *Acacia flavescens*, *Alphitonia excelsa* (although this tree was also newly recorded to one other site in 2007), *Corymbia dallachiana*, *Cymbopogon bombycinus*, *Heteropogon triticeus* and *Hyptis suaveolens*.

The species that were new records for more than one pair of sites in 2007 were *Aristida* sp., *Cochlospermum gillivraei*, *Grewia retusifolia*, and *Pterocaulon radulens*. Juveniles of the bloodwood *Corymbia clarksoniana* were new to a few sites, but were probably just mistakenly considered saplings of *Eucalyptus acmenioides* in 1982.

In 2007, the three sites burnt within the last ten years (sites 3, 5 and 7) had a significantly higher number of species than the remaining sites unburnt for at least 16 years (t = -2.25; P = 0.074, see Figure 1).

Figure 1. The average number of plant species per site in 2007, grouped by fire history. Error bars are 1 standard error.

The native herbs *Flemengia parviflora*, *Galactia tenuiflora* and *Trichodesma zeylanicum*, the grass tree *Xanthorrhoea johnsonii*, native grasses *Mnesithea rottboellioides* and *Themeda triandra*, and exotic grass *Melinis repens* were only seen in sites burnt within the last 10 years (i.e. sites 3, 5 or 7).

The average percentage cover of grass was significantly higher in the sites burnt within the last ten years (3, 5 and 7) than the sites which had been unburnt for at least 16 years, which contained very little grass cover (t = -3.76; P = 0.013). This was the case even though sites 5 and 7 contained only a single year's grass growth since a 2006 fire.

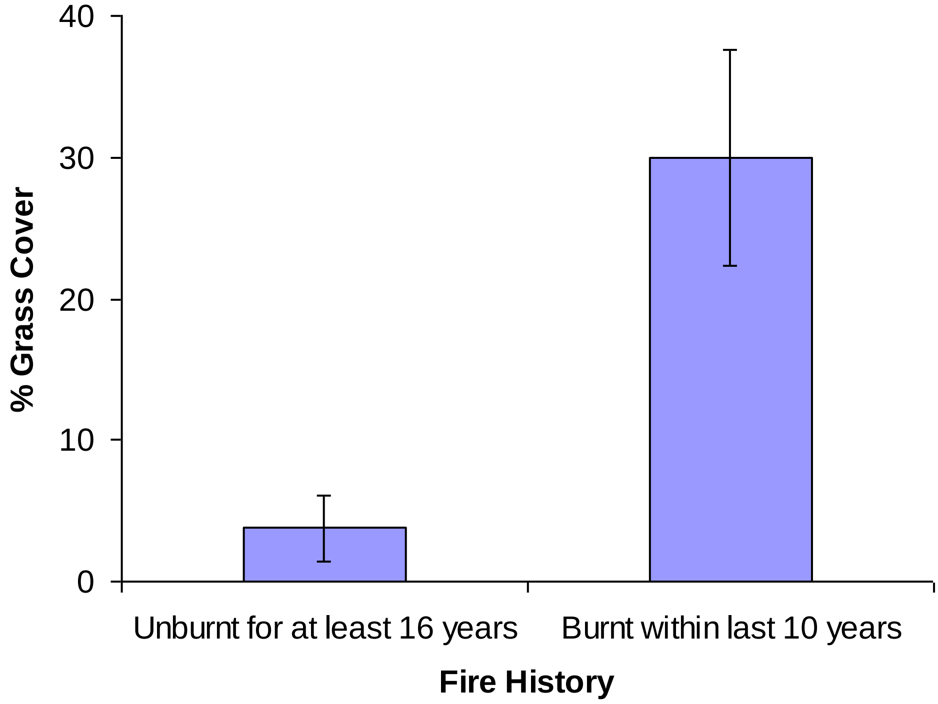

Figure 2. The average percentage grass cover in sites with different fire histories. Error bars are 1 standard error.

The grass layer had disappeared from sites 1 and 2 by 2007, even though in 1982 they were categorised as having a “tall dense grass” fuel type. In 1982, sites 1 and 2 contained a dense 1 to 1.5m ground cover of the native grass *Heteropogon triticeus* (giant spear grass), with “some” *Cymbopogon bombycinus* (lemon grass) and the exotic herb *Hyptis suaveolens*. Photo monitoring from 1984 to 1993 (1992 for site 1), shows that during the period that sites 1 and 2 were burnt moderately regularly (i.e. site 1 in 1977 and site 2 in 1982; sites 1 and 2 both burnt in 1987 and 1991) the grass cover remained dense (above approximately 30% cover), including abundant *Heteropogon triticeus*. Both *Heteropogon triticeus* and *Cymbopogon bombycinus* disappeared from sites 1 and 2 by 2007, in the absence of fire for 16 years.

In 2007, *Cymbopogon bombycinus* was moderately common (5 % or more cover) in all sites that were burnt within the last 10 years and at a low density (< 0.5 % cover) in the long unburnt site 4, in which it and *Themeda triandra* were described as “dense” in 1982.

In 1982, *Themeda triandra* (kangaroo grass) was recorded in the site pair 3 and 4 and in site 5. It remained present in sites 3 and 7, both burnt in the last 10 years. Carolyn Sandercoe made special reference in her 1982 notes that *Cymbopogon bombycinus* and *Themeda triandra* were each present in both sites 3 and 4, with more *Cymbopogon bombycinus* relative to *Themeda triandra* in site 4 and the opposite in site 3. Photo monitoring showed the decline in grass cover in site 4, last burnt in 1982, occurred gradually, from > 50 % grass cover in 1984 to approximately 10 to 15% cover in 1993 (11 years post fire). By 2007, *Themeda triandra* had disappeared from site 4, in the absence of fire for 25 years. In contrast, there was 25% cover of *Themeda triandra* in site 3, burnt 10 years previously. Of interest is the fact that the grass layer remained present in site 3 during the absence of fire during the 1980’s.

The weed Rubbervine, *Cryptstegia grandiflora*, was new to sites 1 and 2 in 2007, each unburnt since 1991. However, there were only three plants in total and all appeared recently established amongst the dense leaf litter, being thin stemmed and about 20 cm tall.

The weed *Lantana camara* was recorded present as a single shrub in the 1982 survey of the site pair - sites 6 and 7. In 2007, five clumps (each > 1 m diameter) were present in the long unburnt site 6. One *Lantana camara* clump (approximately 1 m wide) was present in the frequently burnt site 7, although that clump was against the walking track, so that it may not get burnt with much intensity during fires. Two large *Lantana camara* clumps (one clump being 5 m wide) and a seedling had established in long unburnt site 4 by 2007. No *Lantana camara* were recorded there in 1982.

The long unburnt sites were not invaded by new woody species, such as the rainforest expansions documented in the Wet Tropics. The few trees in the sites that could be considered typical of rainforests, *Canarium australianum*, *Diospyros geminata*, *Mallotus philippensis* and *Timonius timon* were present in the sites originally in 1982. The only rainforest plant recorded in 2007 but not in 1982 was a single 2 m tall shrub *Polyalthia nitidissima* in site 6, which was long unburnt even in 1982. Comparisons of 1980's photos suggest this plant may have been present in 1984.

Vegetation structure
In 1982, the tree canopy of sites 1, 2 and 5, consisted solely of scattered, dead 10 – 13 m tall trees. At that time, a 10 m tall canopy of eucalypts was recorded for sites 3 and 4. Some live 14 m eucalypts grew in sites 6 and 7, although the presence of tall dead trees was recorded in their vicinity.

The heights and composition of the tallest live canopy in 1982 and 2007 are provided in Table 3. Several results can be seen:

1. *Acacia leptostachya*, *Cochlospermum gillivraei* and *Lophostemon grandiflorus* grew at least 2 m in sites 1, 2 and 4, not burnt for 16 years or more.

2. The 8 m tall canopies in sites 1, 2 and 4 thickened over the 25 years, especially *Acacia leptostachya*, *Cochlospermum gillivraei* and *Lophostemon grandiflorus*.

3. A eucalypt canopy was not restored during the 16 years or more absence of fire.

4. The 10 m canopy of *Corymbia dallachiana* and *Eucalyptus drepanophylla* remained stable in site 3, burnt 1977 and 1997.

5. The 14 – 15 m canopy in sites 6 and 7, dominated by *Corymbia tessellaris*, remained stable, even though site 6 was long unburnt and site 7 was burnt four times in 25 years.

6. Saplings of *Corymbia clarksoniana* grew to 5 m in height in site 5, during a fire regime of four fires in 25 years. These 5 m tall bloodwoods had grown from the shrub layer (1.5 to 3 m tall) in 1982. *Canarium australianum* remained at 3.5 m to 4 m during that period.

Table 3. The height, density and composition of the tallest live canopy in 1982 and 2007. Note that the 1982 records covered site pairs, while 2007 surveys documented the structure at individual sites.

Site	1982	2007
1	6 m, very sparse: *Lophostemon grandiflorus*	8 m, dense: *Acacia leptostachya*
2		8 m, dense: *Acacia leptostachya*, *Cochlospermum gillivraei*, *Lophostemon grandiflorus*
3	10 m, moderate(i.e. 30% cover): *Corymbia dallachiana*, *Eucalyptus drepanophylla*	10 m, moderate: *Corymbia dallachiana*, *Eucalyptus drepanophylla*, *Lophostemon grandiflorus*
4		6 m: dense *Acacia leptostachya*
5	3.5 m, sparse: *Canarium australianum*	5 m moderate: *Corymbia clarksoniana*, (Canarium *australianum* 4 m)
6	14 m, moderate (i.e. 40% cover): *Corymbia clarksoniana*, *Corymbia dallachiana*, *Corymbia tesssellaris*	15 m: *Corymbia tesssellaris*
7		14 m: *Corymbia tesssellaris*

The heights, density and dominant species of the shrub and small tree layer (to 4 m height) in 1982 and 2007 are provided in Table 4. Several results can be seen:

1. Several of the dominant species in 1982, especially *Acacia leptostachya*, no longer dominated the < 4 m layer in 2007, as a result of growth during the 25 years and the absence of juvenile plants in 2007.

2. The density of the shrub layer remained sparse in sites 1, 2 and 3; and remained moderate in sites 6 and 7.

3. The density of the shrub layer increased from sparse to moderate density in site 4 (unburnt since 1982) and site 5 (burnt four times in 25 years).

4. The shrubby weed *Lantana camara* increased in abundance in sites 4 and 6, unburnt since 1982 or earlier.

Table 4. The density and dominant species of the shrub and small tree layer (1.5 to 4 m tall) in 1982 and 2007. Note that the 1982 records covered site pairs, while 2007 surveys documented the structure at individual sites.

Site	1982	2007
1	Sparse, in patches: *Acacia leptostachya*, *Cochlospermum gillivraei*	Sparse: *Pogonolobus reticulatus*, *Persoonia falcata*
2		Sparse: *Ficus opposita*, *Pogonolobus reticulatus*, *Persoonia falcata*
3	Sparse, in patches: *Acacia leptostachya*, *A. simsii*	Sparse: *Acacia simsii*, *Diospyros geminata*
4		Moderate: *Alphitonia excelsa*, *Cochlospermum gillivraei*, *Lantana camara*
5	Sparse: *Canarium australianaum*, *Diospyros geminata*, Eucalypt saplings, *Persoonia falcata*	Moderate: *Canarium australianaum*, *Corymbia clarksoniana* saplings, *Diospyros geminata*, *Persoonia falcata*
6	"Common" (i.e. moderate density): *Alphitonia excelsa*, *Canarium australianum*, *Diospyros geminata*, *Mallotus philippensis*, *Persoonia falcata*	Moderate: *Alphitonia excelsa*, *Canarium australianum*, *Diospyros geminata*, *Lantana camara*, *Mallotus philippensis*, *Persoonia falcata*
7		Moderate: *Canarium australianum*, *Ficus opposita*, Mallotus *philippensis*, *Planchonia careya*,

Fuel loads

<u>1982 – 1993 fuel sampling period</u>

The fuel load fluctuated over the study. During the period from 1982 to 1993, fuel fluctuated between years in sites unburnt during those 11 years, (sites 3 and 6), each with a maximum in 1989 and a minimum in either 1983 or 1985. Townsville received 1122 mm of rain in1989, which is approximately "average" rainfall (data from the Meteorological Bureau base at the Townsville airport – see Figure 4). The years 1990 (1668 mm) and 1991 (1530 mm) produced higher rainfall than 1989, but perhaps 1989 was important because it was the first year of the study that wasn't well below "average rainfall".

For sites burnt during the 1982 to 1993 sampling period, fuel loads usually reached a maximum between two and four years after fire, although in site 4 a maximum was reached 7 years after fire (Table 5).

Table 5. Years since fire of maximum fuel weight between 1982 and 1993.

Site	Year of most recent fire	Year of maximum fuel	Years since last fire	Maximum fuel (t/ha)
1	1987	1990	3	11.9
2	1987	1989	2	20.5
4	1982	1989	7	12.2 *
5	1982	1986	4	7.1
5	1987	1989	2	12.1
7	1982	1986	4	8.7
7	1987	1990	3	12.1

* note for site 4, a plateau in fuel load accumulation was reached in 1986, 4 years since fire, at 4.6 t/ha. The fuel subsequently declined, but then increased again to a maximum of 12.2 t/ha in 1989.

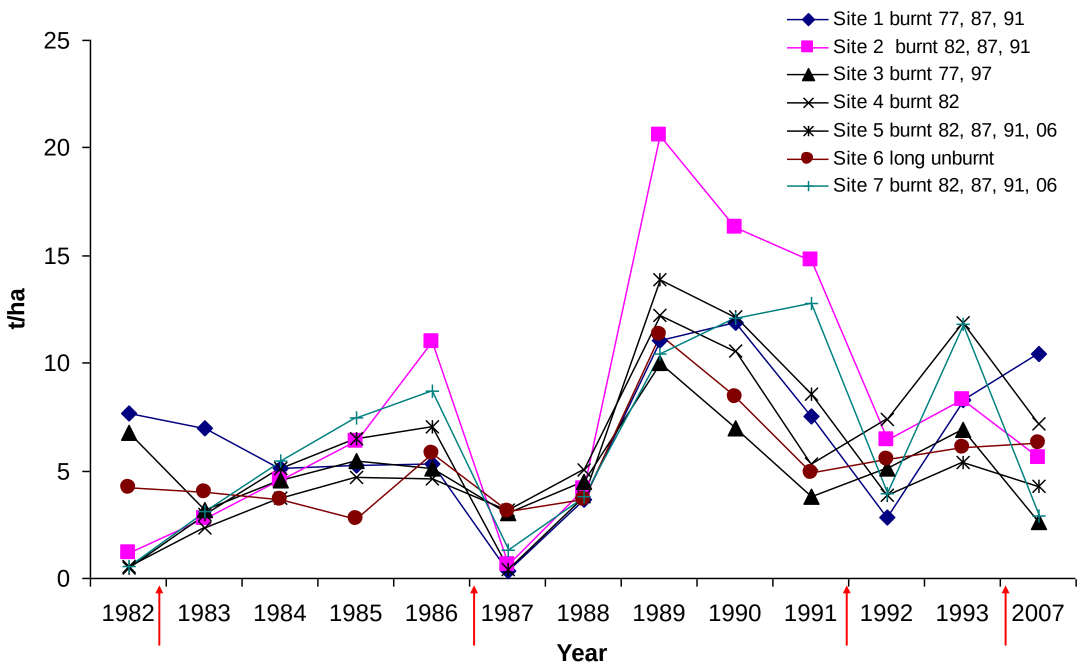

Figure 3. Fuel load fluctuations between 1982 and 1993, and in 2007.
Red arrows along the X axis indicate the timing of fires in the sites:

- 1982 fire burnt – sites 2, 4, 5 & 7 prior to fuel sampling for that year;
- 1987 fire burnt sites 1, 2, 5 & 7 after the fuel sampling for that year;
- 1991 fire burnt sites 1,2, 5 & 7 after fuel sampling for that year; and
- 2006 fire burnt sites 5 & 7.

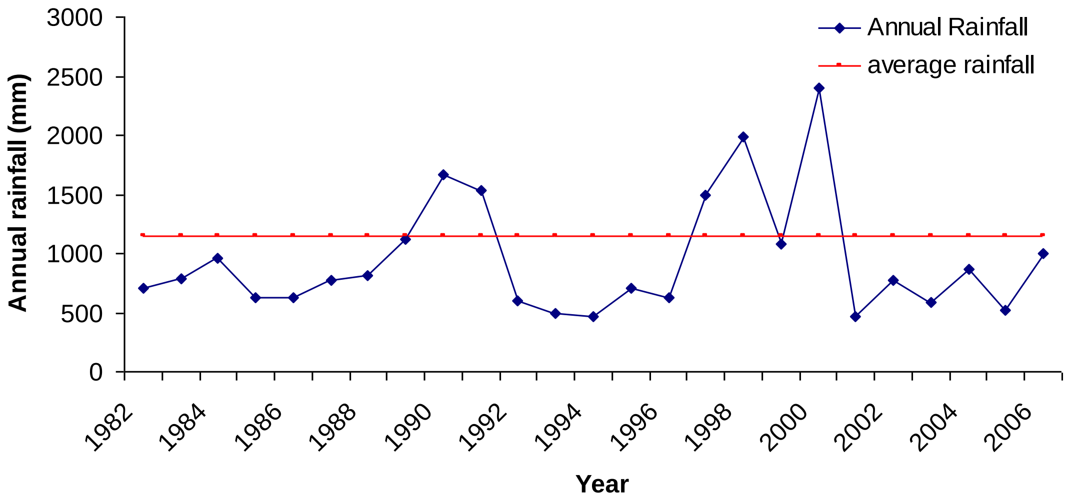

Figure 4. Annual rainfall fluctuations during the study period, measured by the Meteorological Bureau base at the Townsville airport.

<u>2007 fuel samples</u>
In 2007, the fuel load in sites that had not been burnt for 16 years or more was almost completely consisting of leaf litter and twigs on the soil surface. This fuel type was heavier than the mainly grass fuel in sites burnt within the last 10 years. The grass fuels in recently burnt sites was well aerated and reached up to 1.5 m in height, a stark contrast to the surface leaf litter and twigs fuel type in longer unburnt sites.

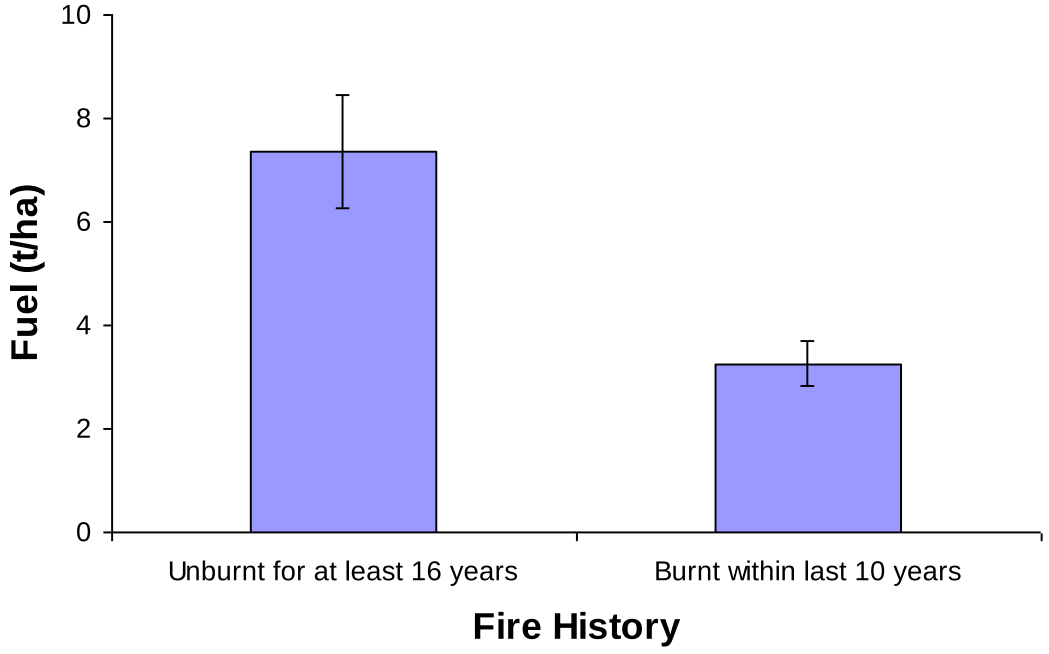

Figure 4. The average fuel loads for 2007, in sites with different fire histories. Error bars are 1 standard error.

Discussion

The grass layer in this woodland disappeared in the absence of fire for 16 or more years, causing a decline in species richness. Photo monitoring demonstrated that the decline in grass cover was not limited to specific years (nor a sequence of rainfall events) but occurred following the cessation of burning in one site in the 1980's (site 4) and again in other sites after 1993 (sites 1 and 2).

Even the most frequently burnt sites in this study (sites 5 and 7, burnt four times in the last 25 years) have a fire frequency lower than that recommended for mixed eucalypt-grassy woodlands on Magnetic Island National Park (Backler & Centurino 2007) i.e. fire intervals of 3 to 5 years. The most recently burnt sites in this study contained an average of 16 species, which is lower than the 29 to 40 species per 100 m^2 recorded in similar woodland in the nearby Bowling Green Bay National Park, that is burnt every two to four years (Williams *et al*. 2003). Frequently burnt woodlands with dense grass layers in the Darwin region also contain 30 to 40 species per 100 m^2, and the absence of burning for more than ten years leads to a significant reduction in their species number (Fensham 1990). It is therefore probable that more frequent fires than experienced in any of the sites in this study (i.e. fire intervals of 3 to 5 years) would promote greater plant species diversity in the grass layer than is currently present.

The canopy of sparse dead tall eucalypts, present in 1982, was not replaced by the growth of saplings into tall trees during the study, irrespective of fire. The best growth of eucalypts was *Corymbia clarksoniana* saplings growing to 6 m in the absence of fire for 16 years, and to 5 m during a fire regime of four fires in 25 years. The absence of fire of four years has been demonstrated to allow some *Corymbia clarksoniana* saplings to grow above 2 m in height, when they are able to re-shoot from branches and continue vertical growth following fire, rather than being reduced to suckers at ground level (Williams *et al*. 2003).

Acacia leptostachya, *Cochlospermum gillivraei* and *Lophostemon grandiflorus* trees grew to produce a dense 8 m tall canopy in sites not burnt for 16 years or more. The shrub layer remained fairly sparse to only moderate density, irrespective of being under a dense or open canopy.

The fuel load fluctuated annually in the absence of fire, with oscillations in annual rainfall. However, there was also a clear link between fuel load and fire history, with fuel loads usually reaching a maximum within two to four years after burning. The absence of fire for at least 16 years led to a change in the characteristics of fuel, with grass fuels being replaced by a thick and heavier layer of leaf litter and twigs. It can be difficult for a fire to travel through the leaf litter and twig fuel type, as the 2006 fire, which burnt sites 5 and 7, did not carry into sites 1 and 2.

In 2007, the leaf litter and twig fuel load in sites unburnt for at least 16 years (7.4 t/ha) was heavier than the moderate grass layer in more recently burnt sites (3.3 t/ha). However, grass fuels in regularly burnt tropical woodlands can be heavier than these leaf litter and twig fuels. The grass-dominated fuel load of these Magnetic Island sites was typically around 10 t/ha within 2 to 4 years after fire in the 1980's. Similar, more frequently burnt woodland in adjacent Bowling Green Bay National Park, also average around 10 t/ha within 2 to 4 years after fire (Williams *et al*. 2003).

Conclusions and Recommendations

At the establishment of this study in 1982, there was a concern that frequent, intense wildfires had caused the death of many eucalypts (Sandercoe 1988 & 1989), in this woodland which has an “of concern” status under the Queensland Vegetation Management Act (1999). Frequent, intense, late dry season wildfires can cause the death of some eucalypt trees, although cyclones, especially Althea in 1971, may also have contributed to tree mortality.

In regards to the tree layer, a dense low canopy (up to 8 m) established in sites unburnt for 16 years or longer. This canopy was dominated by *Acacia leptostachya* and *Cochlospermum gillivraei*. These long unburnt sites contained some dead *Acacia leptostachya* trees but no seedlings. The recovery of eucalypt trees from saplings present in 1982 was remarkably slow, with best growth to 5 or 6 m tall in both long unburnt and frequently burnt sites.

This 25 year study indicates that an abundant and diverse grass layer in this woodland is maintained by regular burning. The absence of fire for 16 years leads to the loss of the grass layer, which may be difficult to restore. Even the most frequently burnt sites in this study (burnt four times in the last 25 years) have a lower plant diversity than similar more frequently burnt tropical woodlands.

The long absence of fire leads to a change in fuel loads, from aerated 1.5 m tall grass fuel to a dense leaf litter and twig cover at the soil surface. This leaf litter and twig fuel load was heavier than a moderate grass load, though less than the grass-dominated fuel of these sites when more frequently burnt. The leaf litter and twigs do not appear to carry fire easily.

It is recommended that fire intervals be returned to averaging every 3 to 5 years in general, with some areas allowed to experience longer periods without fire. This is important to maintain the cover and diversity of grasses and herbs. Fires should primarily be implemented in the early to mid dry season, to ensure low to moderate fire intensity to reduce the risk of causing tree death.

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Appendix: Photo monitoring of the 7 sites on Magnetic Island.
The earliest photos shown here are 1984 or 1985. Photos are available for 1982 or 1984 for all sites, but were taken either immediately after the 1982 fire, or focus on the grass layer without providing a perspective of the canopy.

Site 1: photo taken in 1985

Site 1: photo taken in 2007 (burnt 1977, 1987 & 1991)

Site 2: photo taken in 1985

Site 2: photo taken in 2007 (burnt 1982, 1987 & 1991)

Site 3: photo taken in 1984

Site 3: photo taken in 2007 (burnt 1997)

Site 4: photo taken in 1985

Site 4: photo taken in 2007 (burnt 1982)

Site 5: photo taken in 1985

Site 5: photo taken in 2007 (burnt 1982, 1987, 1991& 1997)


Site 6: photo taken in 1985


Site 6: photo taken in 2007 (long unburnt)

Site 7: photo taken in 1985

Site 7: photo taken in 2007 (burnt 1982, 1987, 1991& 1997)