Eucalyptus grandis (Rose Gum) in northern Queensland: a species under fire

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Abstract

Eucalyptus grandis W.Hill (Rose Gum) is one of a few dominant large tree species in the tall eucalypt forests of northern Queensland. Contrasting views are held over the role of fire in the management of the species. I review current information and present new data on the ecology of *E. grandis* in northern Queensland to inform management to ensure the continued recruitment of the species. *Eucalyptus grandis* is a facultative seeder able to recruit every 2-3 years if its habitat is burnt or otherwise disturbed. Establishment of seedlings and saplings is most frequent in communities with a grass/sedge ground layer and the maintenance of this layer is vital. The species lacks the ability to root sucker but can survive fires by basal coppicing; individuals as small as 2 cm DBH can survive a medium intensity fire while those top-killed will repeatedly coppice. At present a number of drivers, most notably rainforest encroachment, limits both prescribed and wild fires reaching communities in which *E. grandis* occurs. Consequently, recruitment is limited. Regardless of the fire regimes that shaped these communities, I recommend they be burned at a 3-5 year frequency. To ensure this occurs an emphasis should be placed on opportunistic prescribed burning at any intensity and in either early or late dry season.

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Introduction

Management of tall eucalypt forest in northern Queensland is contentious. Opposition to active fire management of these communities has been fed by both emotion backed by anecdotal evidence, and a limited number of – sometimes ill-informed – ecological studies, despite the growing number of detailed research studies in support of regular burning (Harrington & Sanderson 1994; Williams *et al.* 2012; Stanton *et al*. 2014a,b). Consequently, land managers are left with little firm information upon which to design and implement management plans. In northern Queensland, *Eucalyptus grandis* W.Hill (Rose Gum) is often the dominant tree species in the tall eucalypt forest occurring close to rainforest margins. In this paper I review the literature covering the ecology of *E. grandis*, focusing on populations north of the Tropic of Capricorn. I also use personal observations on the species and introduce data collected from (a) eighteen, 20 x 20 m plots on the Herberton Range subjected to a medium intensity prescribed fire in 1993 and monitored between 1993 and 1996 (referred to as Baldy SF Plots), (b) a 2.5 hectare wet sclerophyll plot on the southern Herberton Range monitored from 1978 to 1988 (see Unwin 1989) (referred to as Crater Plot), and (c) data from a vegetation survey of wet sclerophyll forest collected by CSIRO in 1995 and 1996 that was not included in Harrington *et al.* (2000) or Harrington *et al.* (2005) (referred to as Harrington Plots). This review aims to inform fire management of *E. grandis* in northern Queensland and the vegetation communities in which it occurs.

Biogeography

In Australia, *E. grandis* occurs from the Wet Tropics of Queensland in the north to near Newcastle in the south (Florabank 2017). In northern Queensland, the species ranges from the Windsor Tableland in the north to Mount Elliot in the south. There is then a 200 km gap before the next population on the Eungella Range west of Mackay. The species occurs in a range of vegetation communities, both as the dominant canopy species and as a part of a mixed species community. It is commonly found in mesic habitats most often adjacent to rainforest, in moist creek lines and gullies, or on ridges where it intercepts moisture laden air. A large proportion of communities containing *E. grandis* occur in discontinuous patches on the western side of rainforest in the Wet Tropics, while on the eastern slopes the species occurs down to an altitude of approximately 400 m (DEHP 2017a). Queensland Government vegetation mapping (DEHP 2017b) notes *E. grandis* as the dominant canopy species in five Regional Ecosystems in the Wet Tropics and Central Queensland Bioregions. It is also present in other Regional Ecosystems, often associated with *E. resinifera* Sm. (*E. pellita* F. Muell. at lower altitudes), *Corymbia intermedia* K.D.Hill & L.A.S. Johnson, *Allocasuarina torulosa* L.A.S.Johnson and *Syncarpia glomulifera* Nied. subsp. *glomulifera* (Harrington *et al.* 2005). Harrington & Sanderson (1994) introduced a classification of tall eucalypt forest classification based on the dominance of *E. grandis* in the community and then the degree of rainforest invasion within. They identified three communities with *E. grandis* as the dominant species with various stages of rainforest invasion, and two as a component of mixed species community with and without rainforest invasion. A further two drier, woodland communities may have *E. grandis* as a component along watercourses. Natural hybrids of *E. grandis* x *E. teretecornis* Sm. are common in slightly drier areas, while hybrids of *E. grandis* x *E. resinifera* (MB personal observation) and *E. grandis* x *E. pellita* (DEHP 2017a) occur in wetter areas.

Life history

Eucalyptus grandis flowers every 2-3 years in March to May (CSIRO *unpubl.*; Harwood 1990), with flowering observed in stems as small as 13 cm DBH in response to cyclone disturbance (Crater Plot). In North Queensland, it does not hold its seed in the canopy, although reports of persistent capsules for at least a year may be a trait of the species in southern Australian populations (Florabank 2017). It does not need fire to stimulate seed drop (personal observation) and has the potential to recruit from seed frequently if the seed drop coincides with a suitable ground or understory disturbance. Medium to large scale disturbances have historically been created by fire but small scale soil disturbance can be a stimulus for seedling establishment. The life history of *E. grandis* places it as a facultative seeder with recruitment from a regular, frequent seed crop, and the ongoing survival of the adult. Under the regenerative strategies after canopy destruction recognised by Nicolle (2006), it is best placed as a combination resprouter that is able to regenerate from basal coppices as a sapling and epicormic buds as an adult. However, conditions required to produce intense fires are uncommon in the Wet Tropics, particularly so in rainforest and tall open forests (Little *et al.* 2012).

A consequence of this mode of regeneration is the common presence of *E. grandis* in mixed aged stands (Figs 1,2). Seed fall often coincides with fire disturbance. Hence recruitment frequently results in communities with a range of stem ages. However, within mixed aged stands there are obvious pulses of regeneration that likely result from super favourable conditions for recruitment occurring on a decadal time frame or longer. This is illustrated at the Crater Plot where an increase in stems of 10-20 cm DBH between 1978 and 1988, from two to 36, suggests a germination and recruitment pulse in the 1960s, 10–20 years earlier. Another feature of *E. grandis* recruitment is the stark differences in stem size distribution across short distances associated with the linear, disjunct and fragmented nature of the vegetation type, which is often intersected by creeks and rainforest intrusions and more recently by roads and human development. On both the Windsor Tableland and Seaview Range, two communities separated by approximately 3 km have contrasting size class distributions suggesting completely different fire and recruitment histories. In the second Seaview Range community, frequent high intensity fires burning in from grazing land over the last 50 years have prevented recruitment.

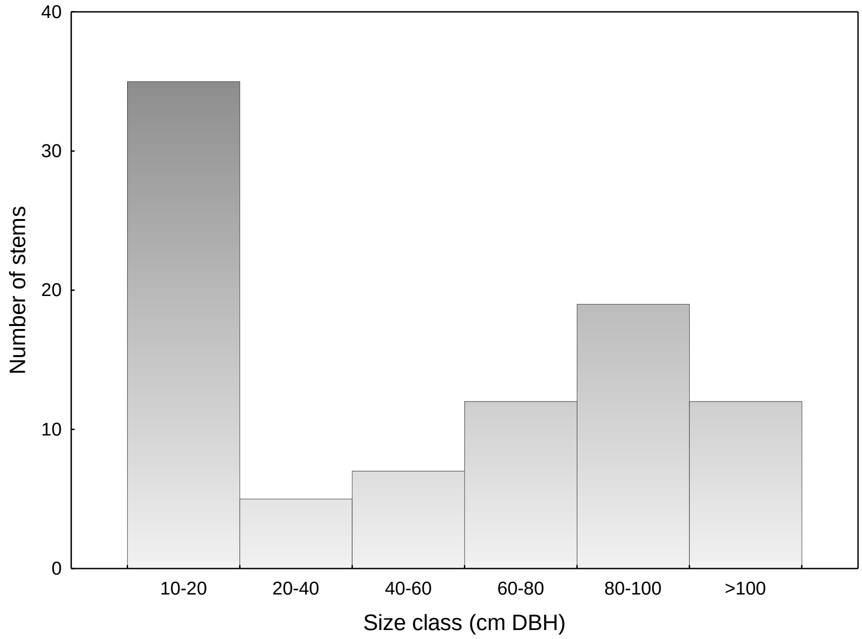

Figure 1. Size distribution of *Eucalyptus grandis* in tropical tall eucalypt forest with a mixed understory in the Crater Plot on the Herberton Range near Atherton, Queensland in 1988.
Individuals <10 cm DBH were not recorded.

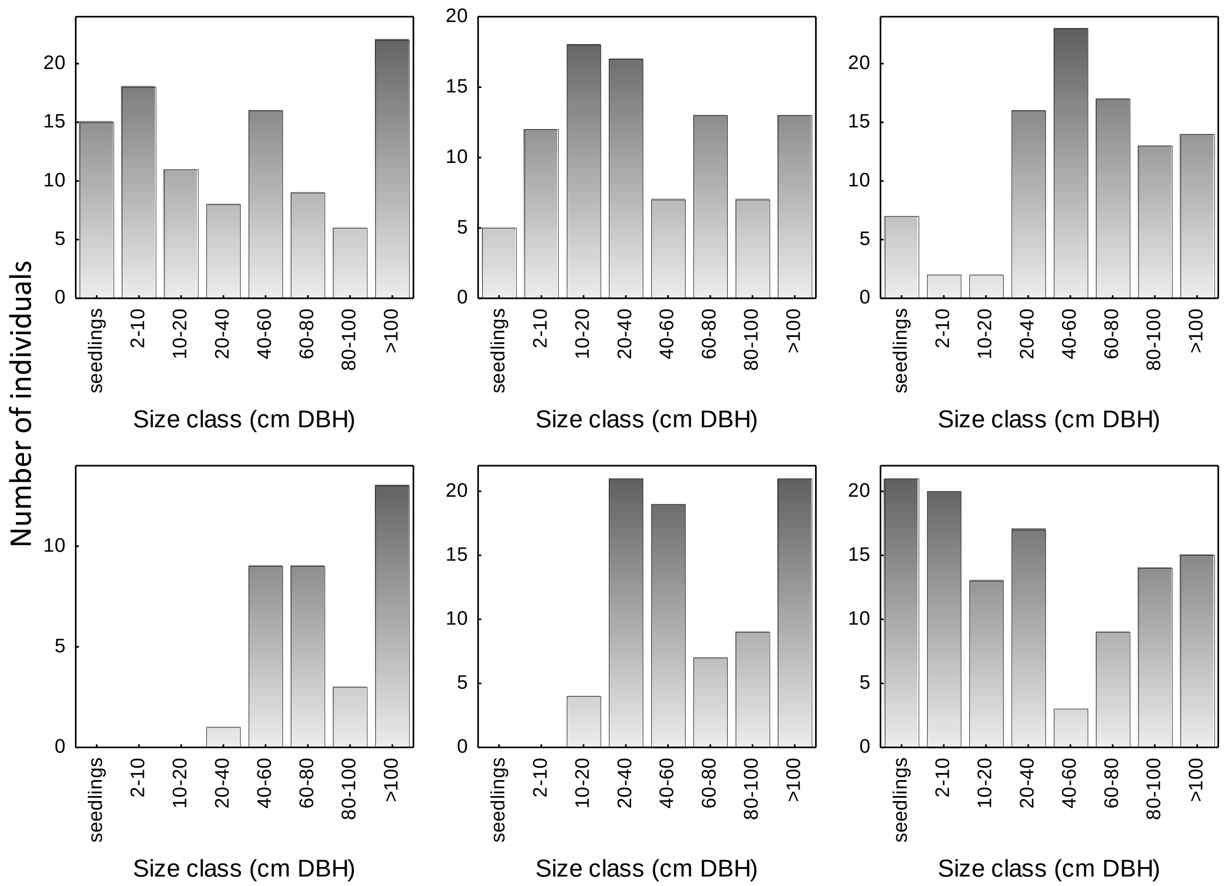

Figure 2. Size distribution of *Eucalyptus grandis* in tropical tall eucalypt forest with a mixed understory using data from the Harrington Plots (see Harrington *et al.* 2000).
In each case data was only used from one discrete *E. grandis* community where the number of 20 x 20 m plots was ≥25 (equivalent to 1 ha). Clockwise from top left: Koombooloomba, Lamb Range, Seaview Range, Windsor Tableland, Windsor Tableland, Seaview Range.

However, a small number of favourable fire events would allow rapid recruitment into smaller sizes.

Recruitment of *E. grandis* is favoured by temporary gaps created by fire in an understory that is dominated by grass and sedge (Williams *et al.* 2012). Data from Harrington Plots (n=843, 20 x 20 m plots) showed that, across the Wet Tropics, the frequency of both *E. grandis* seedlings (<2 cm DBH) and saplings (2-10 cm DBH) in a predominantly grass/sedge understory was 3.9 times higher than that with a predominantly rainforest understory. Eucalypt forest with a mature rainforest understory featured no individuals <10 cm DBH. In the Baldy SF Plots, seedling presence one year post fire was 2.9 higher within a grass/sedge understorey within a young rainforest understory, although the percentage survival three years post fire was no different ($t_{(1,12)}$=0.88, P=0.39). Again, no germination or recruitment was observed within a mature rainforest understorey. However, such events do occur when a large light gap is produced by fire (Russell & Franklin 2018).

Eucalyptus grandis does not exhibit root suckering that allows vegetative regeneration away from the parent but it will readily produce basal and epicormic coppices after fire or damage (Fig. 3). Examination of populations from across the species' range, including from a number of populations from northern Queensland, showed no evidence of lignotubers *per se* in seedlings of any *E. grandis* (Burgess & Bell 1983). Therefore basal coppicing results from epicormic buds at or below the soil surface. In the Baldy SF Plots, one quarter of stems 0–2.5 cm DBH and one third of stems 5–10 cm DBH initially survived a fire, with survival rates increasing considerably with stem size (Fig. 4). Smaller stems that are initially top-killed by fire will readily basal coppice. Williams *et al*. (2012) report 9% basal coppicing of two year old seedlings. Subsequent observations of that population in 2016 indicated the coppice shoots had reached 2 m in height after surviving a further three fires – thus surviving a total of four fires in twelve years since germination (Paul Williams,

Figure 3. Basal coppicing from a 1.5 cm DBH *Eucalyptus grandis* stem-killed by a medium intensity fire three months earlier.
The coppice stems are 45 cm tall and are surrounded by Blady grass (*Imperata cylindrica*).

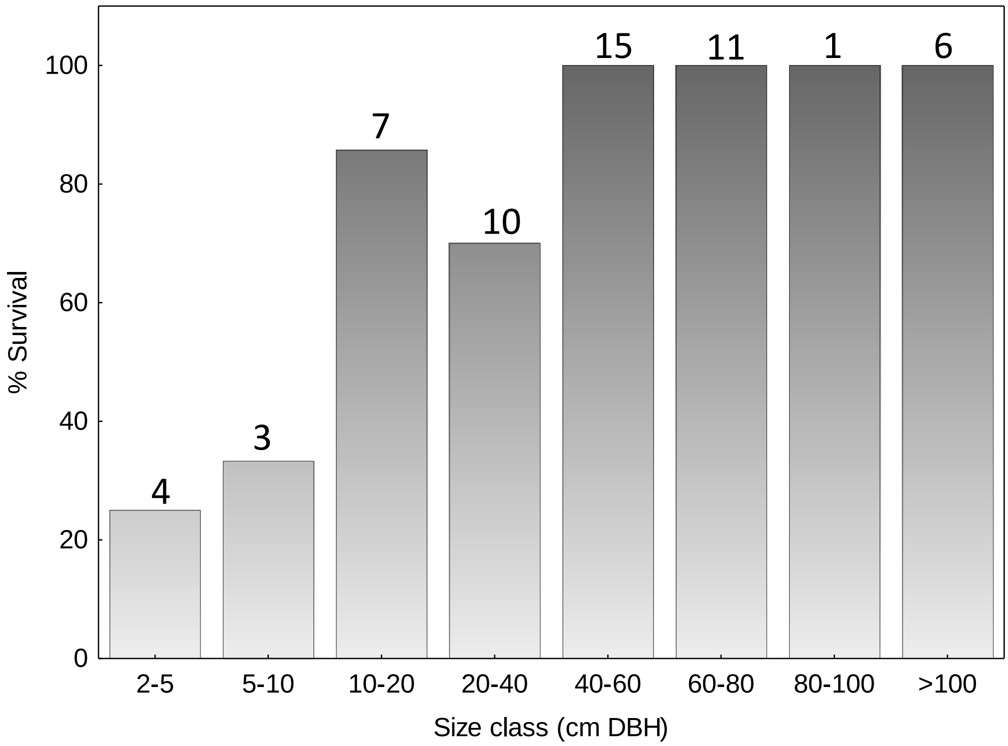

Figure 4. Initial survival of *Eucalyptus grandis* stems one year post medium intensity fire on the Herberton Range (Baldy SF Plots).
Numbers above bars represent number of stems present before the fire. All but one stem (32 cm DBH) surviving to one year went on to survive four years. Two top-killed stems in the 2–5 cm class, and one in the 5–10 cm class produced a basal coppice within one year with the coppice surviving to four years. Two stems in the 20–40 cm class produced epicormic shoots.

personal communication). In the Baldy SF Plots, basal coppicing occurred in three of the five top-killed stems <10 cm DBH post fire. The maximum size of plants producing basal coppicing in the Baldy Plots was 7.5 cm DBH and individuals larger than 7.5 cm DBH either survived intact or produced epicormics shoots.

Eucalyptus grandis is a fast growing species, and controlled field studies in Australia report seedling and sapling height increments in the order of 3.5 metres per year and diameter increments of 3 cm per year (Burgess *et al.* 1996). In a natural system where shading and nutrient competition are present, growth rates will be lower and data from the Crater Plot confirms this, with yearly growth of approximately 1 cm DBH in smaller stems although variation is high due to low sample sizes (Fig. 5). Further observations by Russell & Franklin (2018) show diameter growth of approximately 2 cm and height growth of 2 m in a year post fire within a disturbed mature rainforest. These growth rates allow an individual to achieve a size that will survive a fire after 3 years and a size that will likely survive a fire without coppicing after 5–10 years.

Stand structure and biomass

Around the world, trees exceeding 70 m in height are somewhat arbitrarily defined as giant trees. While *E. grandis* individuals in sub-tropical Australia attain heights that place them in the giant tree category (Wood *et al*. 2015; Florabank 2017), individuals in north Queensland do not meet this criteria. Mean canopy heights of 46 m (Harrington *et al.* 2000) and 48 m (Wood *et al.* 2015) and maximum recorded heights of 60 m (Harrington *et al.* 2000) place individuals in northern Queensland below giant tree status. However, they are amongst the tallest species in northern Queensland and only the Hoop pine (*Auracaria cunninhamii* Aiton) with individuals measured at 65 m on Cape York Peninsula (MB, personal observation) exceed these heights. Rainforest trees in northern Australia attain a maximum height of 50 m with mean heights of 25–35 m being more usual (Bradford *et al.* 2014). In most cases this allows *E. grandis* canopies to stand higher than adjacent rainforest, see Unwin (1989), allowing them to intercept moisture from clouds which may be up to

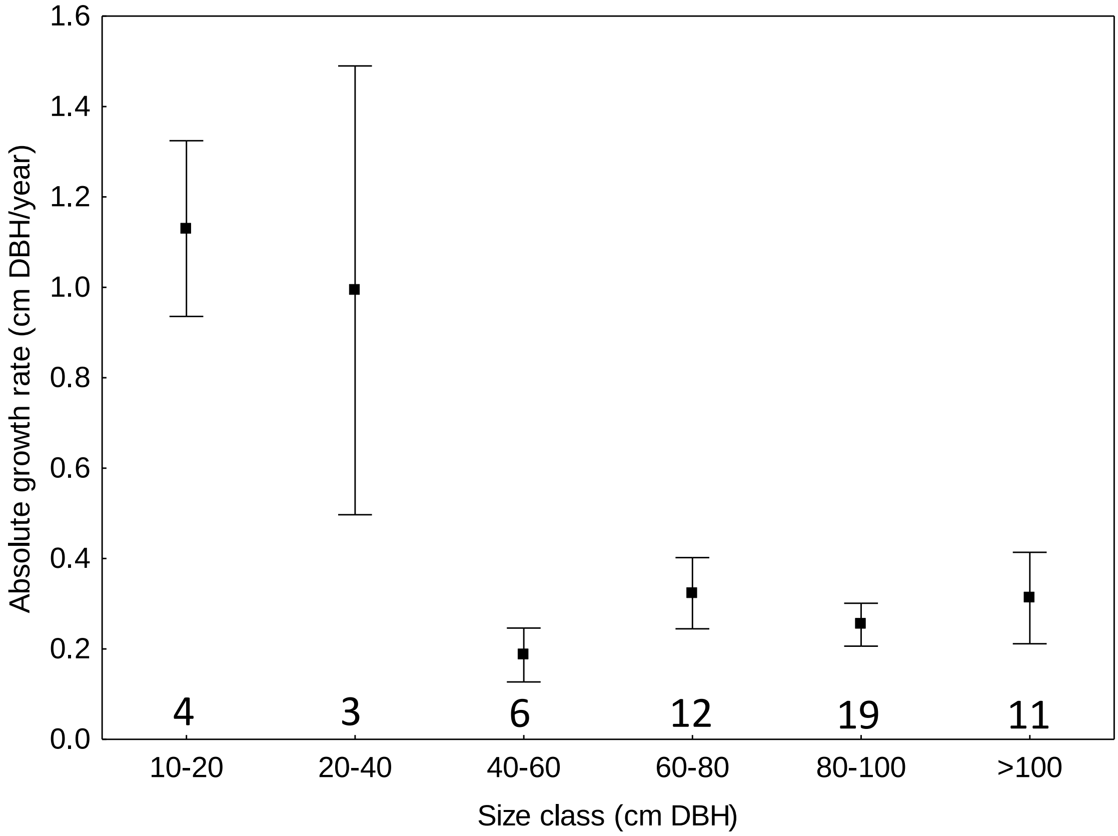

Figure 5. Absolute growth rates of *Eucalyptus grandis* stems in the Crater Plot over a 10 year period. Bars are ±1SE. Sample sizes are shown above the x-axis.

two thirds of total moisture input to an individual (McJannet *et al.* 2007) at altitudes >1000 m.

Above ground biomass (AGB) estimates of *E. grandis* dominated forests in northern Queensland are reported as 154–340 Mg/ha (Wood *et al.* 2015) and 371 Mg/ha (Crater Plot; AGB calculated using Keith *et al.* (2009) and Chave *et al.* (2005)) with *E. grandis* contributing 67% of the biomass (Crater Plot). These AGB values are generally half that of tall eucalypt forest in subtropical and temperate regions including forests containing *E. grandis* in northern NSW (Wood *et al.* 2015). Biomass values are also lower than adjacent rainforest areas which range between 307–909 Mg/ha (mean 590) in the Wet Tropics (Murphy *et al.* 2013). The rainforest plot paired with the Crater Plot has an AGB of 505 Mg/ha.

Ecological Importance and threats

While no vascular plant species is restricted to *E. grandis*-dominated communities, the Department of Environment and Heritage Protection (2017b) in its Regional Ecosystem descriptions lists a number of shrub species closely associated with the tall eucalypt forest. All of these species are residents of high light and mesic environments and will not recruit under a rainforest canopy. There is evidence that certain bird species are dependent on the open understory of wet sclerophyll communities and Chapman & Harrington (1997) identified at least three species that are disadvantaged as wet sclerophyll communities suffer rainforest encroachment. The closest relationship between an animal species and *E. grandis* communities is the almost exclusive use of *E. grandis* hollows by the Yellow-bellied Glider in northern Queensland (Smith and Russell 1982; Bradford & Harrington 1999). The distribution of this species is restricted to communities containing both *E. grandis* and *E. resinifera,* its major food source. The loss of medium and large stems of *E. grandis* would significantly affect hollow availability for the Yellow-bellied Glider in northern Queensland.

The linear and disjunct nature of *E. grandis* communities and the narrow environmental zone the species can occupy means that these communities are restricted and of management concern. The encroachment of rainforest into

E. grandis communities is now well recognised in the literature and by land managers. Five research papers have recently highlighted encroachment of rainforest species into areas previously occupied predominantly by sclerophyll species, and with an open understorey (Unwin 1989; Harrington & Sanderson 1994; Tng *et al*. 2012a; Williams *et al*. 2012; Stanton *et al.* 2014a). Ultimately, this advance becomes irreversible. In some cases *E. grandis* recruitment advances ahead of the expanding rainforest (Unwin 1989) but this is likely to be limited by moisture unless rainfall or moisture patterns change at the same pace.

A further immediate and widespread threat to recruitment in *E. grandis* communities is the prevalence of the environmental weed Lantana (*Lantana camara* L.). The abundance of frugivorous birds from adjacent rainforest allows Lantana to colonise quickly, and high rainfall and abundant sunlight make for perfect Lantana growing conditions. The Crater Plot was transformed from a grass and sedge dominated ground layer with no Lantana recorded in 1988 to a complete cover of Lantana in 2006 (after 18 years), with grass, sedge and sclerophyll recruitment completely compromised. Unfortunately, Lantana readily and repeatedly coppices after fire.

Discussion

Recent research papers (Tng *et al*. 2012b, 2014) have recommended abstaining from using fire as management tool in *E. grandis* communities. These views are based on perceived similarities of *E. grandis* communities in the tropics with southern Australian tall forests combined with unsubstantiated assumptions about the basic ecology of the species. Puzzlingly, Tng *et al*. (2012b, 2014) place *E. grandis* as an obligate seeder alongside such giant southern eucalypts as *E. regnans* F.Muell. and *E. delegatensis* R.T.Baker, in which the adult is killed by fire and recruitment subsequently occurs by seed released from the canopy. However, *E. grandis* is a basal and epicormic resprouter, so this assumption is not supported by the known fire response of the species in the tropics. As *E. grandis* does not behave as an obligate seeder, this is an unfortunate assumption upon which to base important management recommendations. Regular fire produces mixed aged stands from frequent seedling establishment and recruitment. Equally puzzlingly, Tng *et al*. (2012b) also state that high intensity fire is necessary for seedling establishment and recruitment of *E. grandis*, but this is also incorrect. It is commonplace to observe *E. grandis* seedling establishment after low intensity fires. In fact, seedlings will establish after a fire of any intensity, with recruitment to larger classes being favoured by high light conditions provided by understory thinning. Saplings will quickly reach the stage where they can coppice basally in the event of a subsequent low or high intensity fire. Management recommendations erroneously based on obligate seeding and a requirement for high intensity fires are confusing for land managers and highlight the importance of long term ecological studies over short term observations.

Extensive research into the management of tall eucalypt forest in northern Queensland (Harrington & Sanderson 1994; Williams *et al.* 2012; Stanton *et al*. 2014a,b) supports the use of fire as a management tool. However, making a broad brush fire frequency recommendation for a particular vegetation community presents challenges. *Eucalyptus grandis* can maintain recruitment if burnt as frequently as every three years and such a recommendation seems reasonable. In reality, however, fire frequency and intensity will vary among populations. Firstly, the fragmented and disjunct nature of the wet eucalypt communities means that considerable resources will be required to sustain a high-frequency fire regime. Secondly, further fragmentation of *E. grandis* communities by urban and rural-residential development, and the need to consider human lives and property, are restricting the areas that can be burnt. Thirdly, restriction of the spread of both early season prescribed and wild fires through the drier eucalypt forests by moist fuel loads, natural barriers and roads results in wetter eucalypt communities being spared. Hence, active ignition in the late dry season is required to burn these wetter communities. Finally, overriding these variables, continued encroachment of rainforest is reducing the flammability of, and hence excluding fire from, large areas and making other areas increasingly difficult to burn. Hence, even where a high frequency fire regime can be achieved, fires are likely to be patchy. In some areas, recruitment will benefit from a mosaic of burns or a varying fire interval as long as a grass/sedge understory is maintained in the longer term.

Current fire management guidelines for *E. grandis* -dominated forest recommend a frequency of 3–5 years for a grassy understory and 6–10 years for a shrubby understory (DEHP 2017b). The demarcation between grassy and shrubby understory is confusing and unnecessary as the understory varies greatly over short distances and will most often be in a transition to a shrubby state. Moreover, if the aim is to transform a shrubby understory to a predominantly grassy understory then a 6–10 year fire interval is too long. I therefore recommend a goal of a 3–5 year fire frequency of any intensity in all communities dominated by *E. grandis.* This recommendation is made with the realization that this will be difficult to achieve at a regional scale, and mosaic and longer interval burns will occur. I therefore reco-mmend that emphasis be placed on the implementation of opportunistic prescribed burning, particularly in the late dry season where fire can be contained within areas where fuel has been removed by early season fires in order to protect human lives and property.

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