Southern Cross University

Forest Research Centre

Friday, April 17, 2020

NSW Independent Bushfire Inquiry
GPO Box 5341
Sydney NSW 2001

Submission – NSW Independent Bushfire Inquiry

To Whom It May Concern,

Thank you for the invitation to provide expert comment to the NSW Independent Bushfire Inquiry. I am a fire ecologist with 23 years' experience working variously as an ecological consultant, researcher and lecturer. Due to this extensive experience, I am a leading regional authority on the management of fire-dependent vegetation communities and their associated values on the NSW North Coast. I have worked extensively advising on restoration, management and environmental impact assessment associated with hazard reduction and ecological burns across both public and private tenures.

My submission to the inquiry relates primarily to the first two inquiry terms of reference and my response to these is briefly summarised in Table 1 below.

Table 1. Submission summary table outlining relevant terms of reference, response summaries and recommendations.

Terms of Reference	Response Summary	Recommendations
1. The causes of, and factors contributing to, the frequency, intensity, timing and location of, bushfires in NSW in the 2019-20 bushfire season, including consideration of any role of weather, drought, climate change, fuel loads and human activity.	At the commencement of the 2019-20 bushfire season, most vegetation in NSW was beyond recommended fire interval thresholds (i.e. overdue for burning). The predominance of long-unburnt vegetation likely resulted in elevated fuel loads and connectivity across the landscape, increasing the likelihood of bushfire ignition and spread.	1. Increase ecologically sound prescribed burning across NSW to ensure at least 50% of native vegetation is within recommended fire-interval thresholds. 2. Develop and maintain a mapping system that compares actual and recommended fire intervals to deliver near real time data on the current fire interval status of all native vegetation across NSW. 3. An education program to raise awareness of the prevalence and ecological consequences of low frequency fire be developed and implemented. 4. Low frequency fire be nominated for listing as a Key Threatening Process in NSW.
2. The preparation and planning by agencies, government, other entities and the community for bushfires in NSW, including current laws, practices and strategies, and building standards and their application and effect.	The management triggers within most NPWS fire management strategies are strongly biased towards fire exclusion, providing only very week direction to implement burns in vegetation that is either due or overdue for burning. These weak triggers likely delay prescribed burns on NPWS estate and contribute to the predominance of long-unburnt vegetation on this and adjacent tenures.	5. Modify the language used in NPWS Fire Management Strategies to ensure management responses are consistent with the fire interval guidelines (e.g. apply fire during threshold window, avoid fire before the threshold window, burn urgently those areas that have passed the threshold window). In particular, the language/terms used should clearly highlight that the period which is 'within threshold' is the target window for active burning.

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Where possible, I have supported comments with reference to published studies. However, for other observations and unpublished data I am willing to be quoted as an expert. Copies of unpublished reports and submissions can be supplied on request

1 Most NSW vegetation was due or overdue for burning prior to 2019-20 bushfire season

1.1 The prevalence of long-unburnt vegetation

Numerous assessments of fire interval status, comparing fire history records with recommended fire intervals, demonstrate that most native vegetation in NSW is either overdue or due for fire. A recent statewide assessment by OEH and Macquarie University (Gallagher 2018) found that 84.3% of NSW vegetation was affected by too infrequent fire, and an additional 13.8% was within the appropriate window for burning (Figure 1). These findings are consistent with a similar assessment of fire interval status on public lands in Victoria (Fire Ecology Working Group 2002), which concluded that fire frequency is too low across the landscape at both Statewide and bioregional scales.

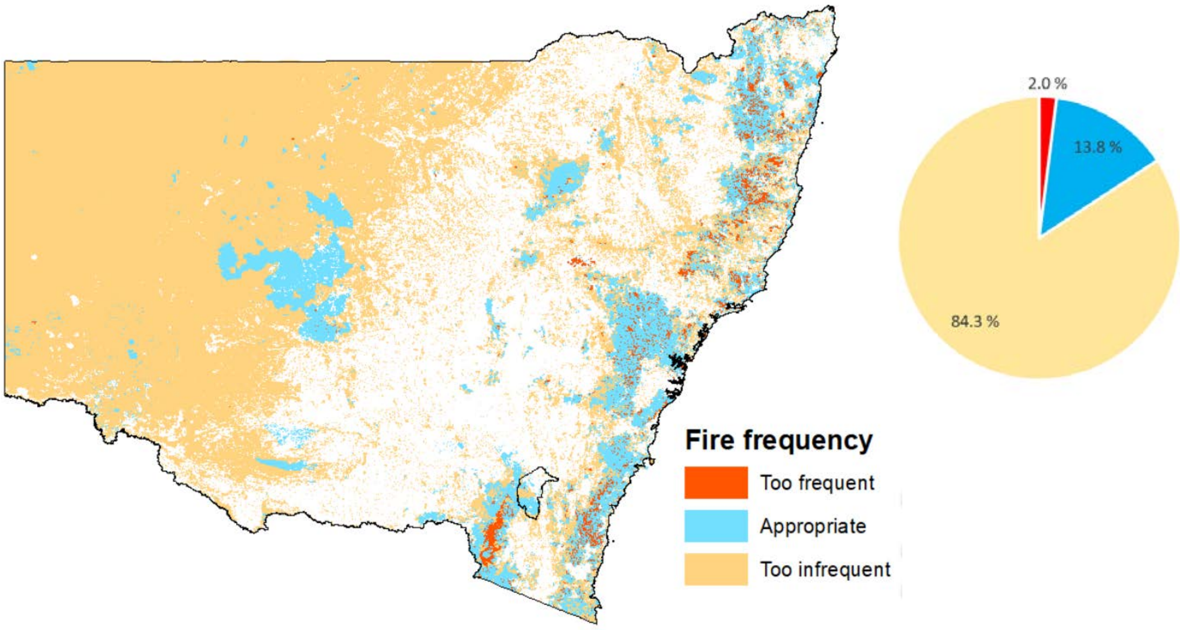

Figure 1. Fire interval status of NSW vegetation in 2018 (Adapted from Gallagher 2018).

Similar assessments at finer scales also demonstrate the comparable predominance of low frequency fire and long-unburnt vegetation throughout coastal NSW. Baker & Catterall (2015) found that across the local government area of Byron Shire, most fire-dependent vegetation was fire-excluded, with less than 10% within recommended fire interval thresholds. Additionally, most fire-excluded areas were fire-excluded for <u>multiple</u> recommended fire-return cycles (Figure 3), increasing the likelihood of elevated fuel loads and fuel connectivity across the landscape. Numerous additional unpublished assessments also show the prevalence of long-unburnt vegetation in other areas of coastal NSW (Table 2; Figure 4; Appendices A-F).

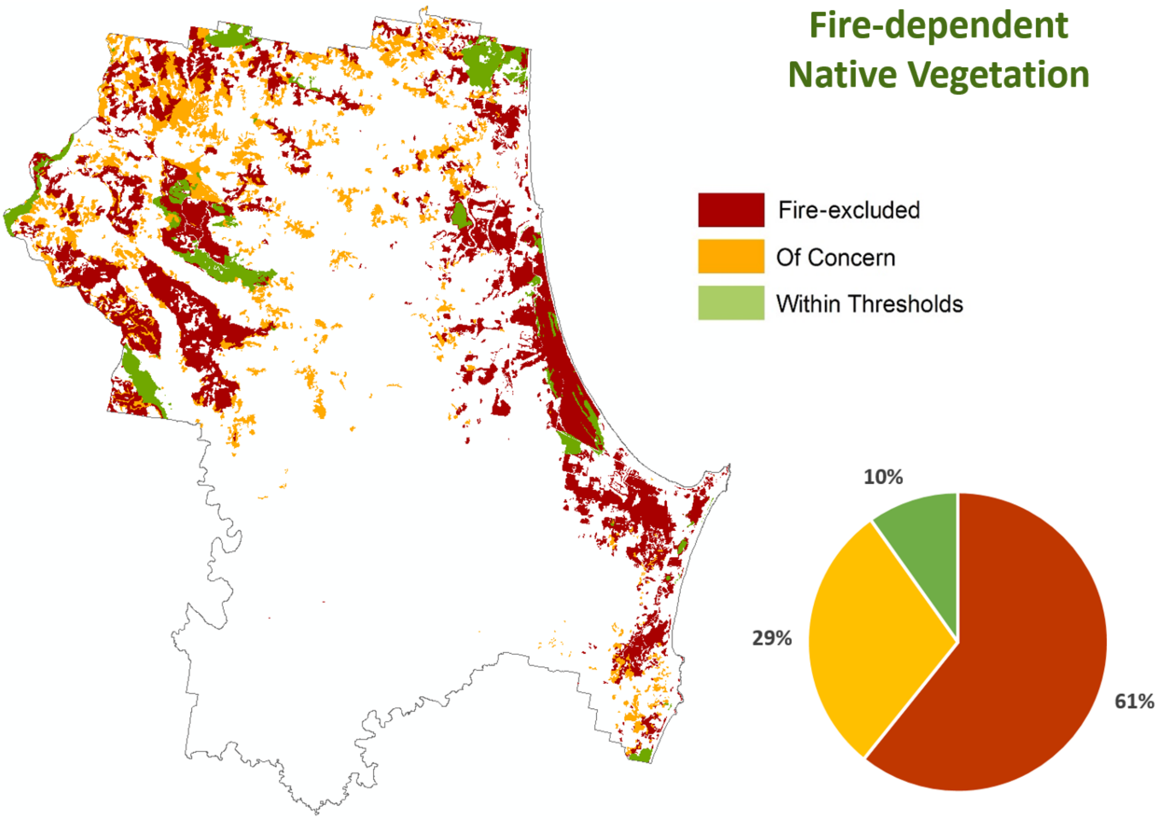

Figure 2. Fire interval status of native vegetation in Byron Shire LGA in 2014. (Adapted from Baker and Catterall 2015).

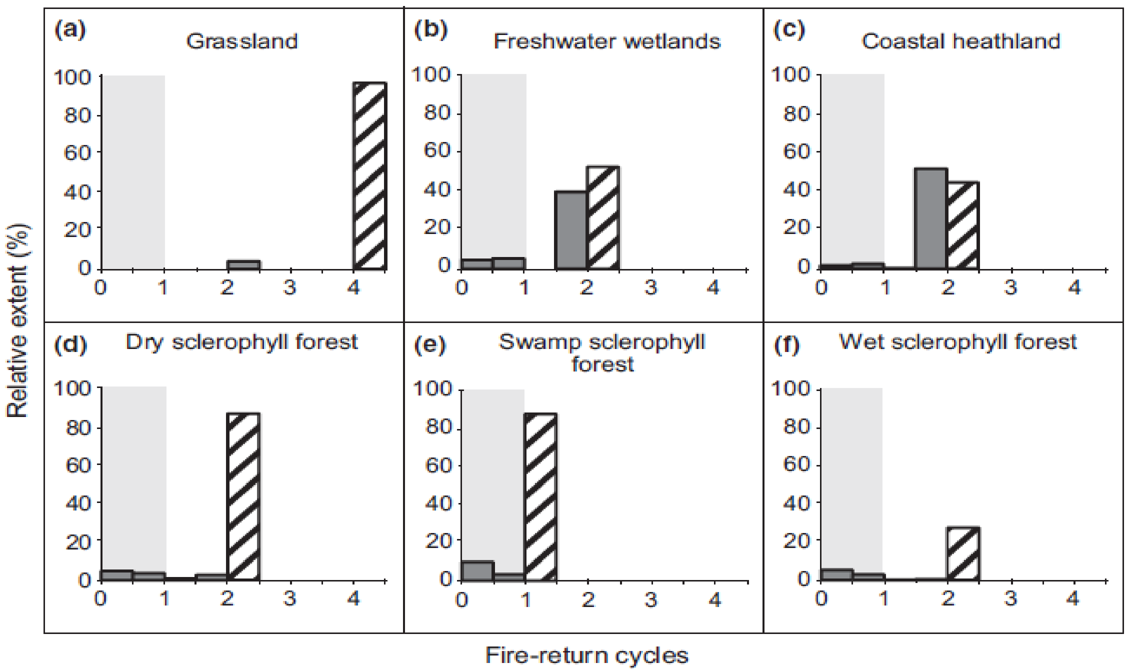

Figure 3. Relative extent of fire-dependent treeless vegetation formations (a–c) and forested formations (d–f) within, or exceeding, fire-interval thresholds in Byron Shire LGA. Bars in the shaded region are within threshold, while bars beyond this region are fire excluded. Hashed bars represent areas unburnt during data period (1974–2014), and may have missed more fire-return cycles than shown. Of concern areas are omitted for wet sclerophyll forest (Source: Baker and Catterall 2015).

Table 2. Additional fire interval status assessments indicating the prevalence of low fire frequency and long-unburnt vegetation in eastern NSW. Percentage ranges shown in status column reflect the use of more than one set of fire interval guidelines.

Value	Region	Status	Reference
Fire-dependent vegetation of the Northern Rivers	NSW northern rivers region	42% fire-excluded 50% of concern (potentially fire excluded OR due for fire)	(NPWS 2013; A. Baker unpublished data; Figure 4)
Swamp Sclerophyll Forest	NSW northern rivers region	38-66% of extent is underburnt, 5-19% will become underburnt within the next 5 years and only 7-4% is of an age class too early to burn this year	(Baker 2019a; Appendix A)
Swamp Sclerophyll Forest	NSW lower north coast	low frequency fire is prevalent	(Baker 2019a; Appendix A)
Coastal Koala Habitat	Tweed LGA (coastal)	45% of extent is underburnt	(Baker 2016; Appendix B)
Coastal Floodplain Eucalypt Forest	NSW Far North Coast	73-99% extent is underburnt 94-99% of all remnants underburnt	(Baker 2019b; Appendix C)
Coastal Floodplain Eucalypt Forest	NSW south coast (Shoalhaven and Eurobodalla LGAs)	low frequency fire affects c. 62% of extent and remnants	(Baker 2019b; Appendix C)
Coastal Swamp Oak Forest	NSW northern rivers region	83-94% of extent is underburnt 69-86% of adjoining fire-dependent vegetation is underburnt	(Baker 2017; Appendix D)
Coastal Swamp Oak Forest	NSW mid north and central coasts	low frequency fire is prevalent	(NPWS 2005, 2006a, 2014)
Coastal Swamp Oak Forest	NSW south coast	low frequency fire is prevalent	(NPWS 2013b)
Coast Cypress Pine Forest	NSW northern rivers region	45-59% of extent is underburnt	(Baker 2019c; Appendix E)
Grey Box – Grey Gum Forest	NSW northern rivers region	52-96% of extent is underburnt	(Baker 2019d; Appendix F)

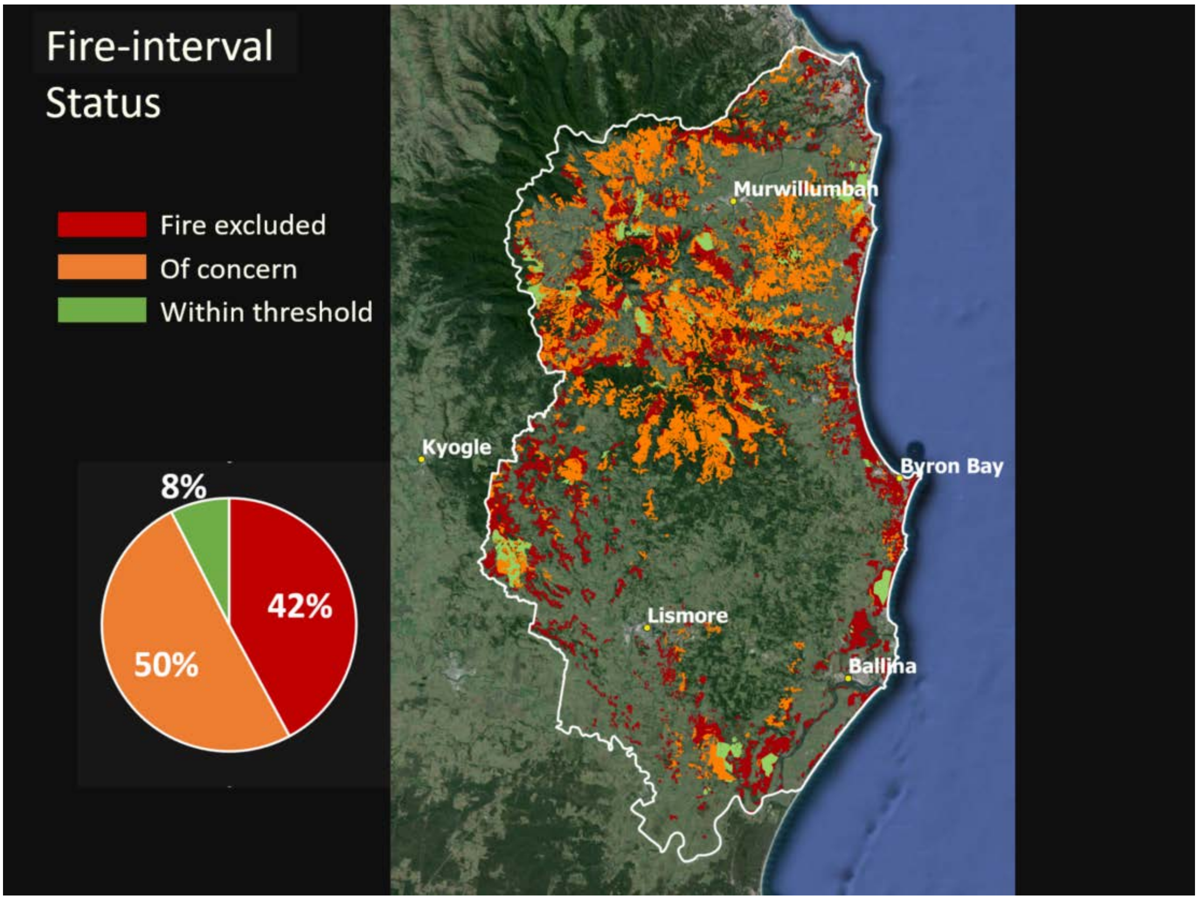

Figure 4. Fire interval status of native vegetation in the NSW northern Rivers region in 2015 (NPWS 2013; A. Baker unpublished data).

1.2 Fuel load typically increases with time since fire

The prevalence of long-unburnt vegetation across NSW is likely to increase bushfire risk. Fires consume fuel, and the exclusion of fire is widely recognised to allow fuel accumulation, thereby increasing vegetation flammability and maximising the likelihood of large, high intensity bush fires. Fire intensity and extent is largely governed by the volume and continuity of understorey vegetation, particularly surface fuels (i.e. leaf, twig & bark litter), near-surface fuels (i.e. grasses & low shrubs) and elevated fuels (i.e. tall shrubs). With increasing time since fire, these layers progressively accumulate fuel, increasing the likelihood of intense bush fires in fire-excluded vegetation (Sullivan *et al.* 2012). Fuel accumulation is most rapid in the decade after fire, although fuels in all layers can continue to increase for several decades (e.g. 22 years; Gould et al. 2008). By increasing the total fuel load, and allowing ongoing structural development of the fuel bed, fire exclusion increases the rate of spread, flame height and intensity of bush fires, as well as the number and distance of spot fires (McCaw *et al.* 2012; Gould *et al.* 2008).

1.3 Misconceptions of fire frequency and its ecological impacts hamper appropriate fire management

Although there is a prevailing view both in the media and scientific papers of increasing fire occurrence, important exceptions aside, the quantitative evidence available does not support these perceived overall trends (e.g. Fire Ecology Working Group 2002; Baker 2016; Doerr and Santín 2016). If scientists, managers and the public predominantly believe (albeit incorrectly) that fire is too frequent in the landscape, hazard reduction and ecological burn programs are more likely to meet resistance, rather than be actively supported and encouraged. In short, these misconceptions are a major barrier to appropriate fire management.

Accordingly, it is essential that awareness of the actual fire-interval status of native vegetation in NSW is increased among scientists, managers and the general public. However, even if awareness of the prevalence of low frequency fire was increased, support for action will also require an understanding of the adverse ecological consequences of low frequency fire. Currently this awareness is basically non-existent across all stakeholders.

1.4 Ecological Consequences of Low Frequency Fire

Low frequency fire is an important threatening process affecting open ecosystems, and is attributed to a wide range of detrimental ecological consequences in Australia and globally (e.g. Moreira 2000; Woinarski, Risler & Kean 204a; Bond, Woodward & Midgley 2005a; Nowacki & Abrams 2008; Parr, Gray & Bond 2012; Tasker *et al.* 2017).

Across open ecosystems generally, low frequency fire is attributed to a range of consequences including:

1. structural change and ecosystem displacement
2. localised decline and extinction of open-forest flora species
3. localised decline and extinction of open-forest fauna species
4. reduced flammability and reinforcement of further rainforest invasion
5. facilitate establishment of transformer weeds
6. dieback of canopy dominants & Eucalypt forest displacement

1.4.1 Structural change and ecosystem displacement

Changes in the structure and distribution of fire-dependent vegetation communities due to fire exclusion is a global phenomenon, being particularly well documented in North America (e.g. Heinselman 1973; Abrams & Nowacki 1992; Nowacki & Abrams 2008), Africa (e.g. Manders, Richardson & Masson 1992; Joubert, Smith & Hoffman 2012) and Australia (e.g. Jackson 1968; Fensham & Fairfax 1996; Bowman *et al.* 2013; Stanton *et al.* 2014a; b).

Open-forests and woodlands are characterised by an ‘open’ tree canopy, above an understorey plant community of graminoids, forbs and shrubs (Specht and Specht 1999; Bond and Parr 2010; Kirkman and Mitchell 2006). These understorey plant communities contain the majority of ecosystem plant diversity, provide key forage, shelter and nesting habitat for fauna, and the fine fuel needed for frequent fires to maintain ecosystem structure and diversity (Veldman *et al.* 2015; Murphy *et al.* 2016). In these systems, regular disturbance (fire, herbivory) promotes high understorey density and richness, by preventing competitive exclusion of grasses, forbs and shrubs by taller woody plants (Ratajczak *et al.* 2012; Woinarski *et al.* 2004a). Fire periodically reduces mid-storey cover and regulates the rate of tree population recruitment into the canopy. Without disturbance however, tree cover progressively increases, reducing light, water and nutrient availability for understorey plant species (Close *et al.* 2009; Specht and Morgan 1981; Jackson *et al.* 2007; Hart *et al.* 2005). The relationship of diminishing light and ground flora loss is illustrated in Figure 5.

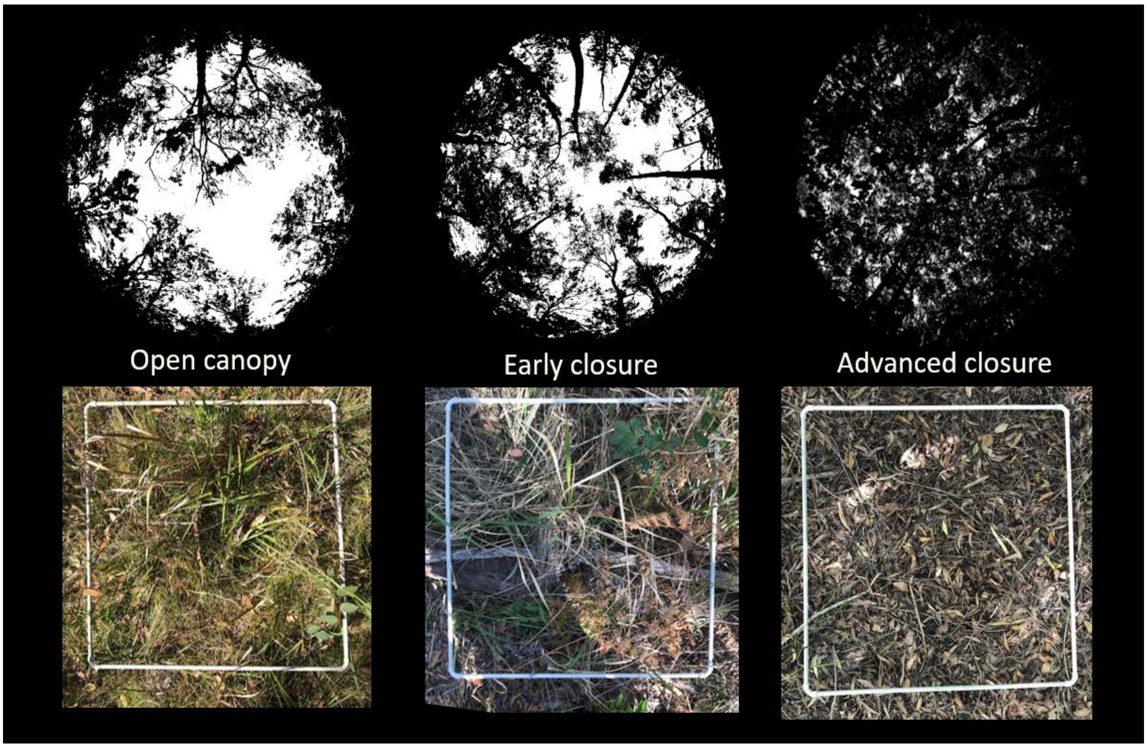

Figure 5. Canopy closure progressively reduces available light (hemispherical photographs at top) resulting in progressive displacement of ground layer flora communities (quadrats at bottom).

Canopy closure and understorey declines in open-forest can result from increased densities of either sclerophyll trees typical of open-forest (e.g. Shackelford *et al.* 2015; Specht and Specht 1989; Lunt 1998), or from fire-sensitive rainforest pioneers expanding from nearby rainforest areas (e.g. Woinarski *et al.* 2004a; Parr *et al.* 2012) (Figure 6). Rainforest invasion of fire-excluded open forests, is a global phenomenon (e.g. Bond *et al.* 2005a; Durigan & Ratter 2006; Nowacki & Abrams 2008), and has been widely reported along the coast and ranges of NSW and SE QLD (e.g. Swain 1928; Fraser & Vickery 1939; Smith & Guyer 1983; Rose & Fairweather 1997; Lewis *et al.* 2012; Butler *et al.* 2014b; Tasker *et al.* 2017). The potential for rainforest invasion of open forests is particularly high in regions of high rainfall (Bond *et al.* 2005a; Fensham 2012), low fire frequency (e.g. Baker & Catterall 2015) and a moderate to high proportion of rainforest tree seed source areas.

A general model of rainforest invasion of fire-dependent open-forests in the absence of fire (see Ashton & Attiwill 1994; Bowman 2000b; Russell-Smith *et al.* 2004; Hoffmann *et al.* 2012a) recognises that rainforest plants often recruit into the open-forests in the interval between fires, but will again be removed or suppressed by regularly returning fires. However, with continued fire exclusion, further growth and recruitment of rainforest plants enables formation of a dense rainforest midstorey (Woinarski *et al.* 2004a; Lewis *et al.* 2012).

Figure 6. Example of canopy closure in fire-excluded open-forest: a) burnt forest with open midstorey (four years post fire), (b) unburnt with dense sclerophyll midstorey (16 years post fire), c) unburnt with dense rainforest midstorey (16 years post fire). Sourced from Baker et al. (2019).

Rainforest invasion in fire-excluded open-forests is also accelerated by global climate change through increased rainfall (Bowman, Walsh & Milne 2001), increased atmospheric humidity (Willett *et al.* 2007), improved forest water-use efficiency (Keenan 2015) and atmospheric CO_2 'fertilization' (Bond & Midgley 2000; Bowman, Murphy & Banfai 2010).

With sufficient time without fire, rainforests may completely displace open forest, as remnant open-forest canopy trees senesce with age or decline prematurely in the unfavourable environment created by the developing rainforest subcanopy (Ellis 1985; Close *et al.* 2009).

1.4.2 Extent of rainforest invasion in fire-excluded open-forest in NSW

While systematic assessment of rainforest invasion in NSW open forests is lacking, the following unpublished data and personal observations (Baker, A) indicate that it is extensive across the NSW north coast and Southeast Queensland and has been observed on NSW south coast.

- Recent vegetation mapping undertaken by Byron Shire Council (1999 & 2016) indicates that c. 90% of dry open forest in the LGA has been invaded by rainforest (i.e. rainforest saplings prominent in the understorey) between these two periods. The mapping indicated that most open forest remnants in Byron LGA were rainforest-invaded. Most open forest remnants that I am familiar with have early to severe encroachment of rainforest trees (e.g. Figure 7b).
- Similar extents of transition are expected in all far north coast LGA's due to fire history and rainforest seed source distribution, although are likely to be less severe in Richmond River LGA where regular fire still occurs in some areas.
- Rainforest invasion into open-forest is relatively common in the following regions:
    - Sunshine Coast (QLD)
    - Brisbane (QLD)
    - Gold Coast (QLD)
    - Far-north coast (NSW)
    - Coffs Harbour – Nambucca Region
    - Port Macquarie
    - Gosford
    - Sydney Region (e.g. Rose and Fairweather 1997)
    - Moruya-Tathra

Figure 7. Comparison of Subtropical Coastal Floodplain Forest (*Eucalyptus tereticornis, Lophostemon suaveolens*) that is a) recently burnt (8 years since fire), and b) long-unburnt (>50 years since fire) and rainforest-invaded.

1.5 Localised decline and extinction of open-forest flora species

A range of mechanisms of flora decline and localised extinction of open forest flora have been associated with low frequency fire, including:

- Premature death of shade-intolerant understorey flora through shading (Keith 1996; Rose and Fairweather 1997; Price and Morgan 2008; Parr *et al.* 2012; Baker, Catterall, Benkendorff and Fensham 2019)
- Failed reproduction and recruitment of flora requiring fire or bare-earth seed beds for germination (Turton & Duff 1992; Ashton & Attiwill 1994; Bremner & Goeth 2010)

Most of the floristic diversity of open forests typically occurs in the ground layer (Specht & Specht 1999) and is shade intolerant (e.g. Benson & McDougall 2002, 2005), making it therefore vulnerable to displacement by dense rainforest midstorey vegetation.

A recent study in fire-excluded heathy Eucalypt forest (Baker *et al.* 2020), found that rainforest pioneers had displaced over half of the understorey plant species, and reduced ground cover and density of dry forest specialists by ~90% (Figure 9). Significant understorey declines also occurred with increased sclerophyll midstorey cover following fire-exclusion, although losses were typically less than half that of rainforest-invaded sites over the same period.

While flora species with persistent soil seed banks may remain on the site until the return of fire, taxa with only transient or canopy-stored seedbanks (e.g. Poaceae, Proteaceae and Myrtaceae) may be at risk of localised extinction (Noble & Slatyer 1980; Keith 1996). Baker et al. (2019) found 20% of displaced plants had no capacity for recovery due to the absence of both a soil seedbank and wide-dispersal capacity. And for a further 68% of displaced species, recovery was limited by the absence of one of these recovery mechanisms. A study of seed-bank longevity in dry forests near Sydney, estimated that 'long-lived' seedbanks may be typically exhausted only 1–2 decades after adults have died, with the plants becoming locally extinct if fire-free intervals exceeded this threshold (Auld *et al.* 2000).

Figure 8. Displacement of understorey plant community in open-forest in Bundjalung National Park, showing regularly burnt forest on left (4 years since fire), and fire-excluded rainforest-invaded open-forest 16 years after fire.

1.6 Localised decline and extinction of open-forest fauna species

In Australia, low frequency fire has been attributed with the declining habitat suitability and displacement of mammals (Fox 1982; Harrington & Sanderson 1994; Laurance 1997; Dennis 2001; Jackson *et al.* 2011), birds (Chapman & Harrington 1997; Garnett & Crowley 2002; Russel-Smith & Stanton 2002; Woinarski, Risler & Kean 2004b; Tasker *et al.* 2017) and reptiles (Webb, Shine & Pringle 2005).

A range of mechanisms of fauna decline and localised extinction of open forest flora have been associated with low frequency fire, including:

- Loss of ground cover foraging, breeding and or sheltering resources as ground layer vegetation lost to canopy shading (Tingay and Tingay 1984; Recher and Serventy 1991; Garnett & Crowley 2002; Leonard 2016; Sitters *et al.* 2016)
- Impeded movement under canopy through midstorey thickening (Saab et al. 2004; Inkster-Draper *et al.* 2013; Blakey *et al.* 2016)
- Reduced hollow formation from fire scarring of canopy trees (Munks et al. 2007; Taylor and Haseler 1993; Whitford 2002; Koch et al. 2008)
- Accelerated decay of woody debris in humid conditions under closed canopy (MacMillan 1988; Tyrrell and Crow 1994; Gholz *et al.* 2000)
- Reduced ectotherm/homeotherm heating opportunities below closed canopy (Templeton *et al.* 2001; Pringle, Webb & Shine 2003; Webb *et al.* 2005)
- Increased exposure to high severity wildfire due to fuel build up at site and landscape scale (McCarthy *et al.* 2001; Gould *et al.* 2008)

- Increased abundance of feral predators in long-unburnt vegetation with reduced groundlayer vegetation (Hradsky *et al.* 2017).
- Reduced age class diversity and structural formation diversity (Whelan 1995; Bond & Van Wilgen 1996; Bradstock, Williams & Gill 2002; Russell-Smith *et al.* 2004; Valentine *et al.* 2012)
- Reduced habitat connectivity (Templeton *et al.* 2001)

Rainforest invasion into Australian open forest has been shown to affect the habitat suitability and species diversity of mammals (Jackson *et al.* 2011; Laurance 1997; Baker, Catterall, Benkendorff and Law 2019), birds (Chapman and Harrington 1997; Russell-Smith and Stanton 2002; Woinarski *et al.* 2004b; Stone *et al.* 2018) and invertebrates (Andersen *et al.* 2006).

For example, a recent study in fire-excluded heathy Eucalypt forest (Baker *et al.* 2019) found that long-unburnt, rainforest-invaded forests had lower bat activity (63% lower) and species richness (35% lower) than recently burnt forests with a more open-mid-storey. The displaced bat species included several threatened species, which were no longer able to forage among the increased stem and foliage density of the invading rainforest trees.

1.7 Dieback of canopy dominants & Eucalypt forest displacement

A dense mid-storey of invading rainforest trees has been demonstrated to accelerate the decline of open-forest canopy trees through:

- Suppressed reproduction and recruitment of canopy trees beneath the dense midstorey (Turton and Duff 1992; Ashton and Attiwill 1994; Ashton 2000).
- Canopy dieback through increased competition, and/or changes to soil pH, nutrient and microbial conditions (Kirkpatrick and Marks 1985; Harvest *et al.* 2008; Close *et al.* 2009; Horton *et al.* 2013).
- increased competition for soil water availability during droughts (Kirkpatrick and Marks 1985; Harvest *et al.* 2008; Close *et al.* 2009);
- alteration of ectomycorrhizal communities mediated by soil chemistry (Ellis and Pennington 1992; Horton *et al.* 2013)
- locking up phosphorous and/or cations in rainforest litter and midstorey biomass (Close *et al.* 2009);
- facilitating Bell Miner Associated Dieback (BMAD) by providing critical nesting conditions for bell miners (C. Stone *et al.* 2008; Stone 2005; Silver and Carnegie 2017).

With advanced canopy dieback, the original Eucalypt canopy is replaced by the invading rainforest subcanopy, and represents the complete displacement of the original Eucalypt forest community on the site.

1.7.1 Fire exclusion and Canopy Closure primes Eucalypt forest for BMAD

The role of low-frequency fire in facilitating Bell Miner Associated Dieback (BMAD) through encouraging development of dense mid-storey nesting habitat is given in Appendix 3 and Silver & Carnegie (2017). In summary, Bell Miners require a mid-storey structure (dense cover at 2-6m in height) to nest and establish colonies. Periodic fire is the principle agent for regulating mid-storey height and density in Eucalypt forests. Fire periodically reduces mid-storey cover through topkill of mid-storey vegetation, which then progressively regenerates with time since fire. However, in the prolonged absence of fire, mid-storeys can develop into ideal Bell Miner nesting habitat. Dense mid-storeys suitable for Bell Miner nesting are now ubiquitous across many areas of long-unburnt open-forest in the Eucalypt foreest of the coast and ranges of NSW.

1.8 Facilitate establishment of transformer weeds

Numerous weed species are fire-sensitive, and like fire-sensitive rainforest trees, their establishment is favoured by fire-exclusion (e.g. Camphor Laurel, Umbrella Tree). Like rainforest trees, these weeds have the potential to form a dense midstorey or canopy and can therefore have the same impacts in open-forests as invading rainforest trees. Accordingly, all weed species with the potential to develop a dense midstorey or canopy should be considered ‘transformer’ weeds. The transformative potential of these weeds includes to:

- o displace open-forest understorey plant communities and canopy trees through competition
- o degrade or eliminate open-forest fauna habitat
- o suppress the flammability of open-forests through alteration of fuel arrays and microclimatic conditions (Brooks *et al.* 2004; Stevens & Beckage 20090).

Figure 9. The transformer weed Camphor Laurel in Subtropical Coastal Floodplain Forest in Byron Shire. The shade beneath the dense subcanopy in this remnant is transforming the community though suppression of groundlayer vegetation and subsequent decline in floristic diversity fauna habitat and community flammability.

1.8.1 The relationship of Lantana and other weeds to BMAD

Lantana is frequently singled out as the primary cause of BMAD and the primary target for associated weed control. While Lantana has been the popular scapegoat for BMAD over recent decades, a rapidly growing body of evidence shows that removal of Lantana alone fails to reduce Bell Miner density or increase canopy health (Horton 2015; Lambert *et al.* 2016, 2017; Lambert and McDonald 2018). Specifically, Horton (2015) found Bell Miner activity was greater on Lantana treatment sites than control sites in Mount Lindsay State Forests, and splatter gun control of Lantana near Kyogle, Armidale and Port Macquarie failed to reduce Bell Miner numbers (Lambert *et al.* 2016; Lambert and McDonald 2018) due to the retention of a dense mid-storey native vegetation. The only reported instance of Bell Miner individuals vacating plots treated for Lantana is where removal resulted in total mid-storey removal (Lambert et al. 2016).

It is now well established that mid-storey structure (dense cover at 2-6m in height), rather than the presence of Lantana, determines establishment of Bell Miner colonies (e.g. Stone *et al.* 2008; Hastings 2012; Lambert and McDonald 2018). For example, Lambert and McDonald (2018) report that Bell Miner have been recorded nesting in at least 37 plant genera, and found that across four study areas including sites with dense lantana, >99% of nests occurred in species other than Lantana. Additionally, on long-unburnt sites, Lantana treatment typically stimulates strong recruitment of rainforest pioneers (e.g. Somerville *et al.* 2011), resulting in rapid recovery of suitable Bell Miner nesting habitat. Therefore, to be effective, treatment must include the overall reduction of mid-storey cover (irrespective of species composition), not Lantana reduction alone.

2 NPWS fire management strategies provide inadequate prompts for implementing prescribed fires in vegetation that is due or overdue for burning

In their current form, many NPWS Fire Management Strategies (Type 2; FMS) are strongly biased towards reinforcing fire exclusion of native vegetation by providing inadequate prompts for implementing prescribed fires in vegetation that is due or overdue for burning. These weak triggers likely contribute to the predominance of long-unburnt vegetation in many areas of NPWS estate in NSW.

NPWS FMS classify and map reserve vegetation into *biodiversity threshold* classes which indicate the fire interval status according to recommended fire intervals (Kenny et al. 2004) for the conservation of biodiversity. The basic premise of the thresholds is that in order to conserve biodiversity:

- fire should be applied within a specified temporal window, and
- fires applied before or after this window should be avoided as they are likely to adversely affect biodiversity (including the exclusion of fire beyond the maximum threshold).

Within the FMS, the ‘Biodiversity Threshold’ tables (Figure 12) typically include:

- a brief description of each threshold class, and
- prompts for management responses for each threshold class

Biodiversity thresholds for Land Management Zones	
Too frequently burnt	Fire thresholds have been exceeded. · *Protect from fire as far as possible.*
Vulnerable to frequent fire	The area will be too frequently burnt if it burns this year. · *Protect from fire as far as possible.*
Within threshold	Fire history is within the threshold for vegetation in this area. · *A burn is neither required nor should one necessarily be avoided.*
Long unburnt	Fire frequency is below fire thresholds in the area. · *A prescribed burn may be advantageous. Consider allowing unplanned fires to burn.*
Unknown	Insufficient data to determine fire threshold.
NB. Fire thresholds are defined for vegetation communities to conserve biodiversity	

Figure 10. Biodiversity thresholds table from a typical NPWS Fire Management Strategy, showing description and recommended management response for each threshold class.

However, despite a rapidly growing body of scientific literature that shows that severe biodiversity consequences can be expected from both too-frequent or too-infrequent fire, the management responses only provide weak prompts to i) apply fire within the appropriate burn window and to ii) apply fire to avoid or address situations where vegetation has passed the maximum threshold to become 'long-unburnt'.

Using *Dry Sclerophyll Shrub Forest* as an example, the recommended fire interval of 7-30 yrs (Kenny *et al.* 2004) based on the ecological literature, suggests that biodiversity will be maintained if fire is applied between 7-30 years since the last fire, but will decline if fire is applied before or after this window (Figure 13). Consistent with these guidelines, 'plain English' management prompts would reasonably state: *don't burn* (<7 years since fire), *burn now* (7-30 years); *burn urgently* (>30 years). While the management prompt for <7 years since fire is appropriate, prompts for the remaining classes are not consistent with the ecological literature. In particular, the 'within threshold' recommendation is patently incorrect in stating that a burn is not 'required', where in fact this is precisely the recommended window to burn for biodiversity conservation.

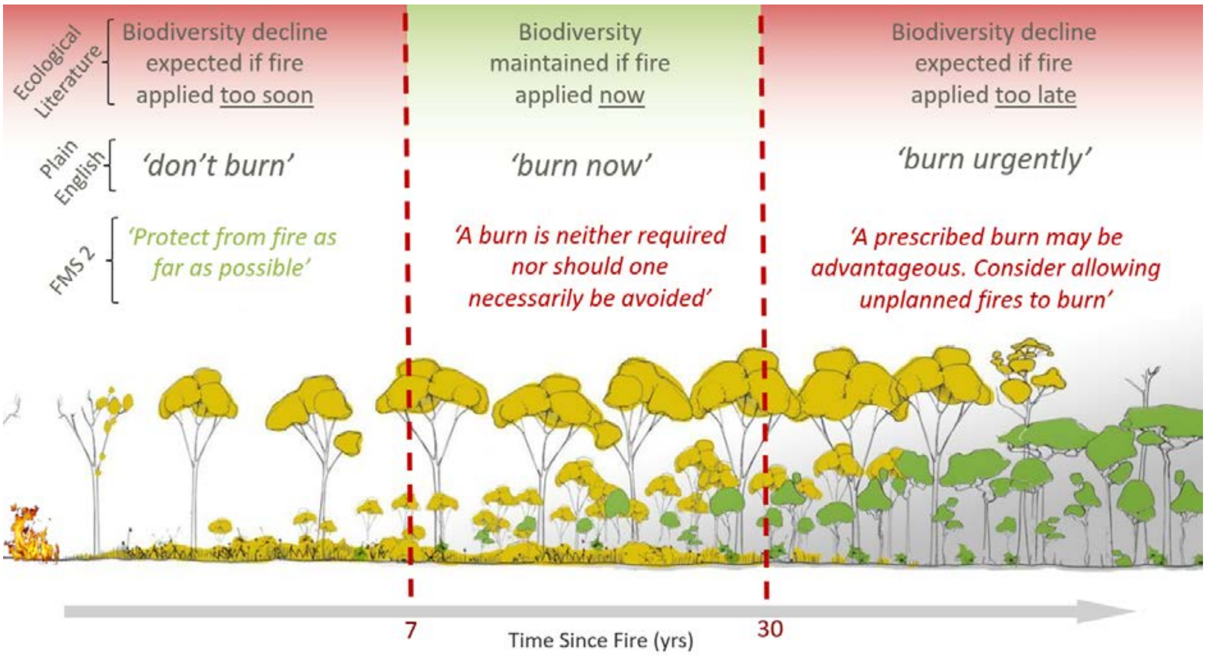

Figure 11. Biodiversity thresholds for 'dry sclerophyll shrub forest' (Kenny et al. 2004) including annotations that illustrate how FMS management prompts for thresholds > 7 years are inconsistent with the ecological literature.

Crucially, the 'biodiversity thresholds' table within FMS are fundamental in guiding decisions of when to apply fire on NPWS lands. Currently, the language used in the FMS threshold table undermines effective fire management on two fronts. Firstly, it directs NPWS managers to generally exclude fire – excluding 'as far as possible' before the burn window, and providing no meaningful prompts to apply fire when burns are due/overdue. Secondly, the language reinforces common, but unfounded misconceptions that i) high frequency fire is a ubiquitous threatening process across NSW (when data shows the opposite to be true in many regions; see section 1); and 2) that low frequency fire is not a threat to biodiversity (despite increasing evidence to the contrary; e.g. Keith 1996; Laurance 1997; Chapman and Harrington 1997; Kenny *et al.* 2004; Jackson *et al.* 2011; Baker *et al.* 2020).

Ultimately, the language used in the FMS tables are likely to delay the timely application of fire within NPWS estate, favouring on overwhelming predominance of older vegetation classes with higher fuel loads and higher fuel connectivity, and thus elevating the bush fire risk in the landscapes of NSW.

3 Recommendations

Further to the abovementioned issues, it is recommended that NSW fire agencies:

1. Increase prescribed burning across NSW to ensure at least 50% of native vegetation is within recommended fire-interval thresholds.
2. Develop and maintain a mapping system that compares actual and recommended fire intervals and provides to fire management agencies and the public, near real time data on the current fire interval status of all native vegetation across NSW.
3. An education program to raise awareness of the prevalence and ecological consequences of low frequency fire be developed and implemented.
4. Low frequency fire be nominated for listing as a Key Threatening Process in NSW.
5. Modify the language used in NPWS Fire Management Strategies to ensure management responses are consistent with the fire interval guidelines (e.g. apply fire during threshold window, avoid fire before the threshold window, burn urgently those areas that have passed the threshold window). In particular, the language/terms used should clearly highlight that the period which is 'within threshold' is the target window for active burning.

Please feel free to contact me if you would like to discuss anything further.

Kind regards, [redacted]

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5 Appendices

Appendix A. Extract from Baker 2019a - Fire Interval Status: Swamp Sclerophyll Forest TEC

Morris & Auld 2003), and creating opportunities for seedling recruitment (Gilbert 1959; Turton & Duff 1992; Ashton & Attiwill 1994; Whelan 1995). The presence of such species indicates a history of fire on the site (potentially hundreds of years where emergent Eucalypts occur), and their prevalence in SSF across the community's range indicates fire is a widespread and crucial ecological process in the community.

While some occurrences of SSF also contain rainforest in the understorey, and this may be argued to indicate fire-sensitivity of the community, rainforest plants frequently occur in open forests subject to regular fire, by establishing between fires and/or persisting after fire by resprouting (Campbell & Clarke 2006, A. Baker, Pers. Obs). Conversely however, plant species dependent on fire for recruitment and persistence cannot exist in communities where fire is excluded.

2.3 Open forest structure

The typical open forest structure of many occurrences of SSF (i.e. open canopy and dense flammable ground layer) indicates that SSF shares similar relationships to fire, as those of open forests generally. It is well established that open forests typically require fire to maintain their open canopy structure (Swain 1928; Jackson 1968; Bowman 2000a; Gammage 2011; Murphy & Bowman 2012). Without fire, canopy closure can occur through increased recruitment of trees into the canopy strata, including fire-sensitive rainforest trees that may ultimately cause a biome shift to closed canopy rainforest. Such changes are known to occur in SSF (NPRSR 2013; DSITI 2014, A. Baker, Pers. Obs.). The other key structural feature of open forests, common also in SSF, is a dense ground layer of flammable graminoids, ferns and forbs (DOE 2017). In open-forests this flammable ground-layer is crucial to facilitating the regular fire needed to maintain open canopy structure, but is often lost if fire exclusion allows canopy closure to shade it out (Murphy *et al.* 2010; Hoffmann *et al.* 2012a; Bowman *et al.* 2013; Butler *et al.* 2014a).

3 THE PREDOMINANCE OF LOW FREQUENCY FIRE IN SSF

Analysis of fire history records (NPWS 2019) using GIS methods of Baker & Catterall (2015) indicate that throughout much of its extent, SSF is predominantly affected by *low-frequency fire* (i.e. beyond recommended thresholds for biodiversity conservation). For example, in the northern rivers region of NSW, comparison of fire history data with both statewide and regionally-specific fire interval guidelines show that 38-66% of SSF is underburnt, 5-19% will become underburnt within the next 5 years and only 7-4% is of an age class too early to burn this year (Figure 1). Similar analyses in the Hunter region indicates that low frequency fire is also predominant in SSF on the NSW lower north coasts (Figure 2) with most areas either overdue or ready for fire.

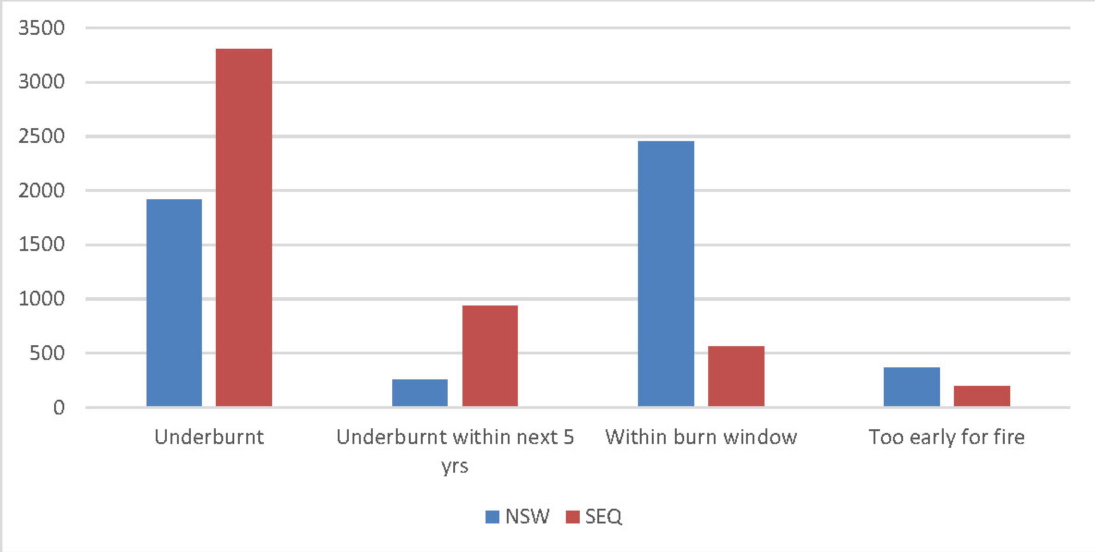


Figure 1. Fire threshold status for Swamp Sclerophyll Floodplain Forest remnants in the northern rivers region of NSW. Fire interval guidelines include NSW (Kenny *et al*. 2004) and SEQ Planned Burn Guidelines (NPRSR 2013).

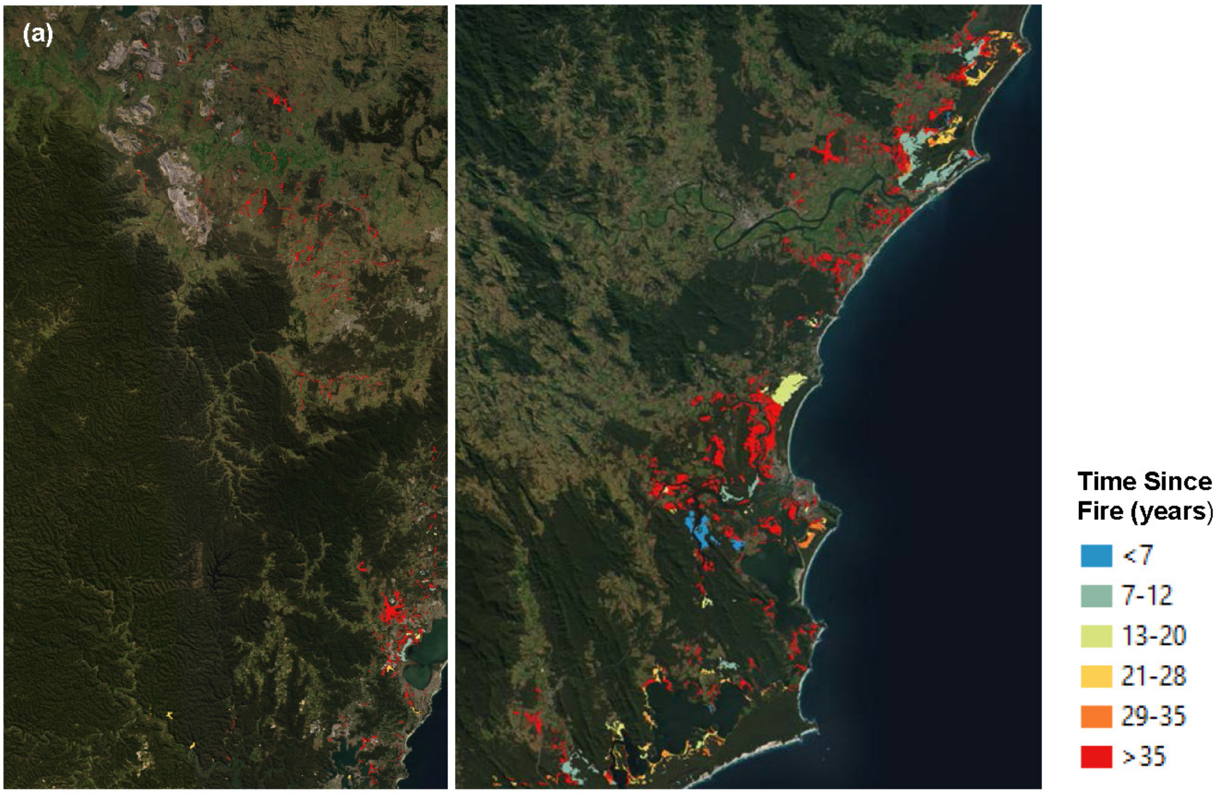


Figure 2. Time since fire in Swamp Sclerophyll Forest in 2017 the Hunter Region a) south and b) north.

5.3 Fire Interval Status

An assessment of fire interval status was undertaken to determine the condition of koala habitat in relation to recommended fire intervals for the maintenance of vegetation condition. The methods of the assessment are outlined in **Appendix A.**

On the Tweed Coast approximately 1,241 ha (45%) of koala habitat is currently beyond recommended burn intervals (i.e. overdue for fire; **Figure 10**; **Map 4**). A well designed and implemented hazard reduction burn program is required to minimise the risk of either of these severe consequences eventuating.

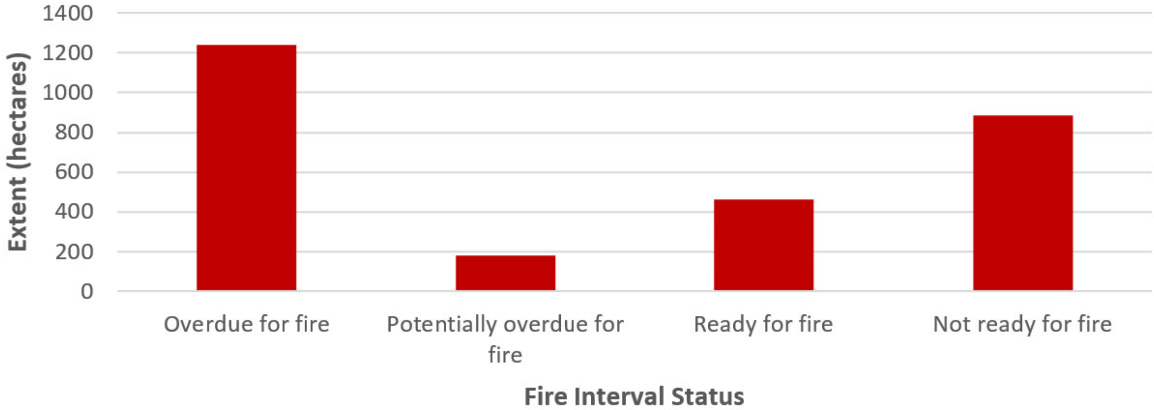
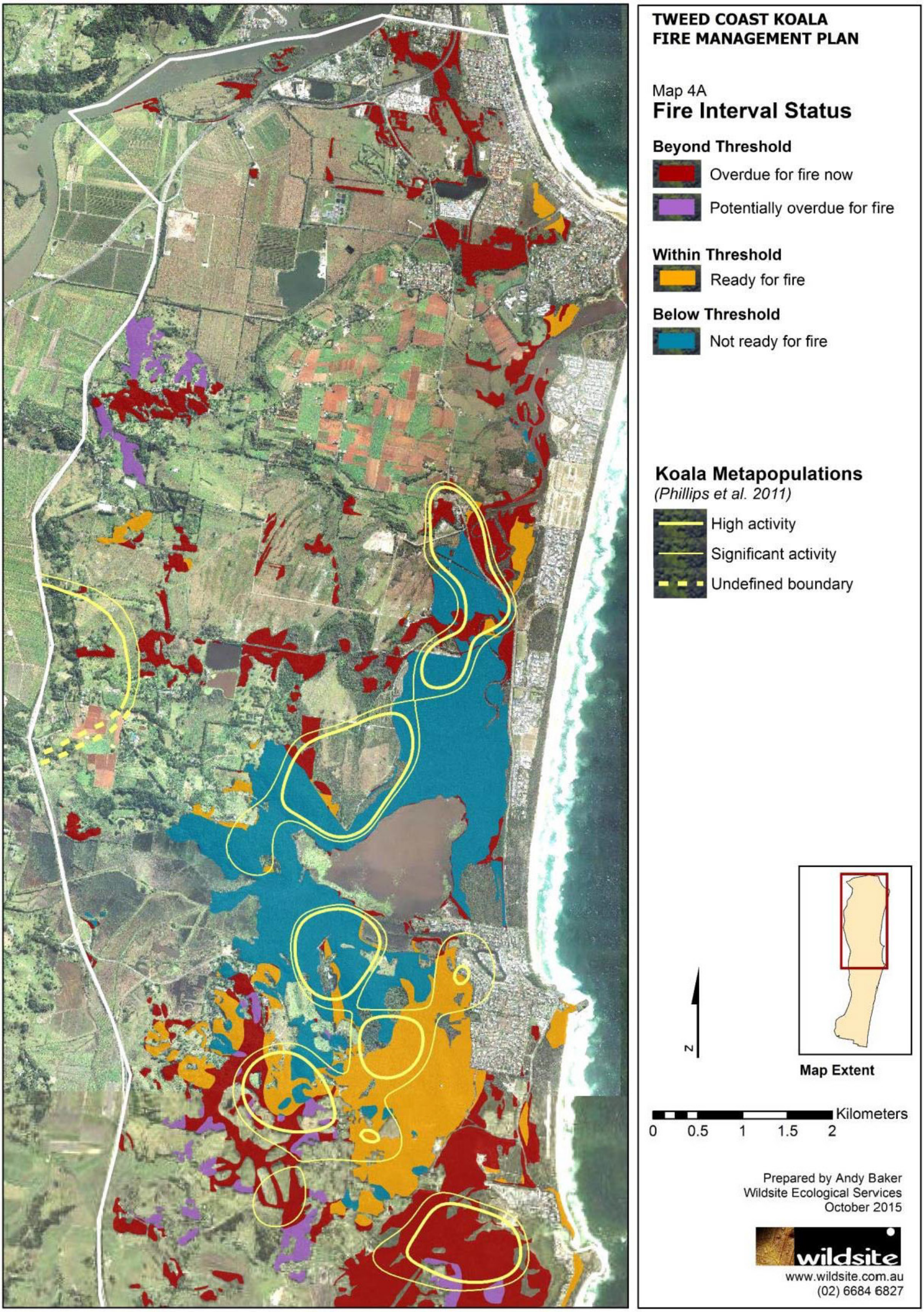


Figure 10. Fire interval status across all koala habitat within the southern KMA.


TWEED COAST KOALA
FIRE MANAGEMENT PLAN
Map 4A
Fire Interval Status
Beyond Threshold
Overdue for fire now
Potentially overdue for fire
Within Threshold
Ready for fire
Below Threshold
Not ready for fire
Koala Metapopulations
(Phillips et al. 2011)
High activity
Significant activity
Undefined boundary
N
Map Extent
Kilometers
0 0.5 1 1.5 2
Prepared by Andy Baker
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October 2015
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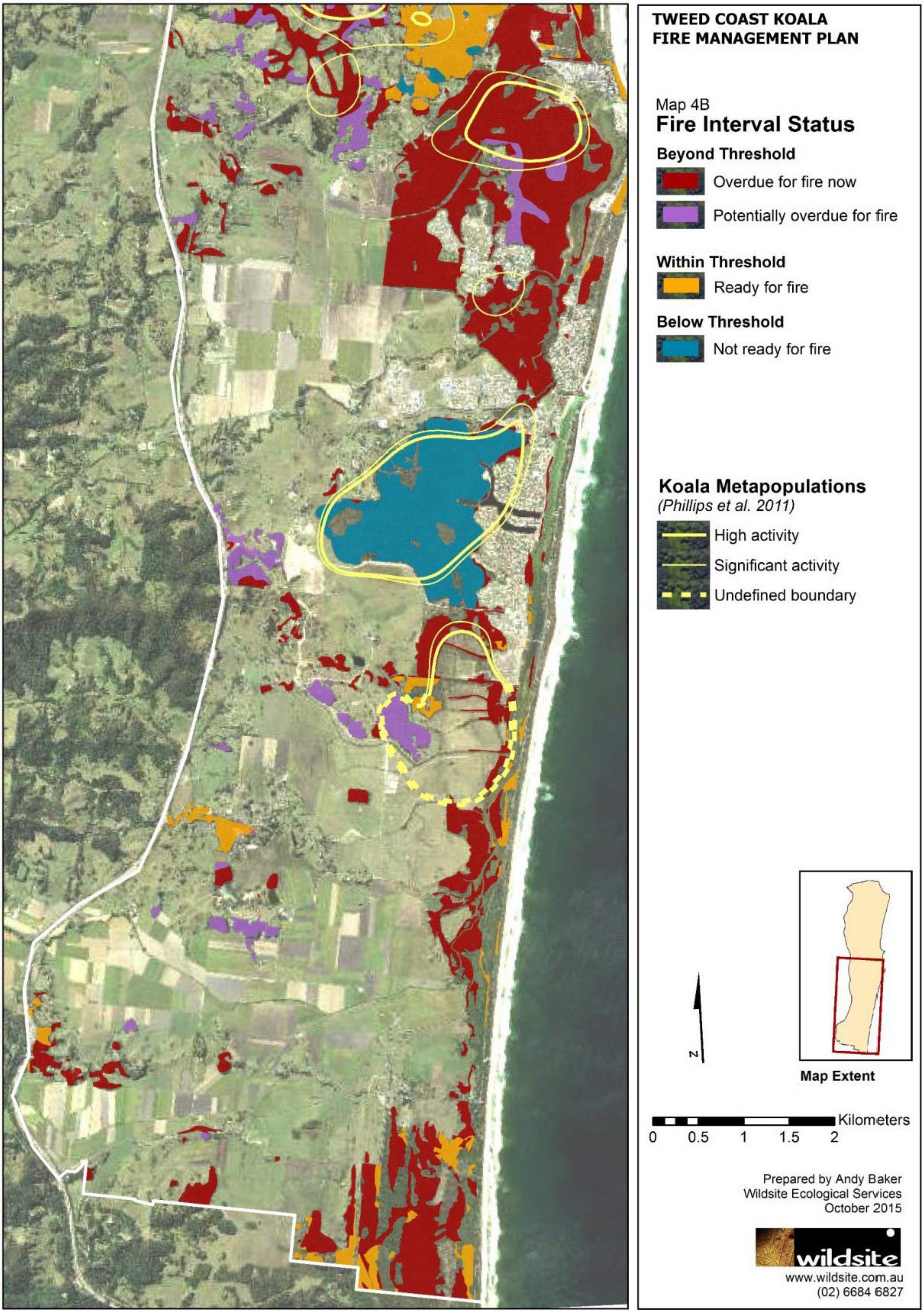
TWEED COAST KOALA
FIRE MANAGEMENT PLAN
Map 4B
Fire Interval Status
Beyond Threshold
Overdue for fire now
Potentially overdue for fire
Within Threshold
Ready for fire
Below Threshold
Not ready for fire
Koala Metapopulations
(Phillips et al. 2011)
High activity
Significant activity
Undefined boundary
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Map Extent
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1 THE PREDOMINANCE OF LOW FREQUENCY FIRE IN CFEF

1.1 Fine interval status

Fire history records (NPWS 2018) indicate that throughout much of its extent, CFEF is predominantly affected by *low-frequency fire*. For example, in the NSW Far North Coast (Tweed, Byron, Ballina LGAs), comparison of fire history data with both statewide (Kenny *et al*. 2004) and regionally-specific fire interval guidelines (NPRSR 2013) show that 73-99% of CFEF is underburnt (Figure 1; Baker, A. unpublished data) representing between 94-99% of all remnants (Figure 1). A similar analysis undertaken for the NSW south coast (Shoalhaven and Eurobodalla LGAs) indicate that low frequency fire affects c. 62% of CFEF extent and remnants. Additional evidence of low fire frequency across the range of CFEF is given for Byron Shire (Baker and Catterall 2015) and Victoria (Fire Ecology Working Group 2002).

Figure 1. Fire interval status for mapped Coastal Floodplain Eucalypt Forest remnants in the northern rivers region of NSW. Fire interval guidelines include NSW (Dry Sclerophyll Forest – grassy; Kenny *et al*. 2004) and SEQ Planned Burn Guidelines (Dry Open Forest – Grassy; NPRSR 2013; See Section 1.2 for more details).

Declining fire frequency in these areas is likely due to i) cessation of Aboriginal burning, ii) fragmentation of landscape fuel continuity by clearing, agriculture and urban development; and iii) fire suppression.

These results contradict DOEE (2019), who imply that the predominant fire-regime change threatening CFEF is an *increase* in ignition rates (i.e. high frequency fire) through grazier burning and hazard reduction (p. 72). While high frequency fire probably affects some remnants of CFEF, the analyses given here and those of Baker (2015) and Fire Ecology Working Group (2002) indicate low frequency fire is the predominant form of inappropriate fire frequency.

1.2 Recommended fire-frequency in CFEF

The recommended fire-intervals for CFEF vary with formation and jurisdiction (Kenny, Sutherland, Tasker, & Bradstock, 2004; NPRSR, 2013; Queensland Herbarium, 2016). Regional guidelines exist for the Southeast Queensland Bioregion (Gladstone – Coffs Harbour), while statewide guidelines exist for the remainder of NSW and Victoria (Table 1).

Appendix D. Extract from Baker 2017 - Fire Interval Status: Coastal Swamp Oak Forest

facilitating the regular fire needed to maintain open canopy structure, but is often lost if fire exclusion allows canopy closure to shade it out (Murphy *et al.* 2010; Hoffmann *et al.* 2012a; Bowman *et al.* 2013; Butler *et al.* 2014a).

3 THE PREDOMINANCE OF LOW FREQUENCY FIRE IN SOFF

Analysis of fire history records (NPWS 2017) using GIS methods of Baker & Catterall (2015) indicate that throughout much of its extent, SOFF is predominantly affected by *low-frequency fire* (i.e. beyond recommended thresholds for biodiversity conservation). For example, in the northern rivers region of NSW, comparison of fire history data with both statewide and regionally-specific fire interval guidelines show that 83-94% of SOFF is underburnt (Figure 2), and 69-86% of adjoining fire-dependent vegetation is underburnt (Figure 3). Similar analyses undertaken by NPWS indicate that low frequency fire is also prevalent in and around SOFF on the NSW mid north and central coasts (NPWS 2005, 2006a, 2014) and south coasts (NPWS 2013). While fire history data for Queensland (NPSR 2017) also suggest low frequency fire may affect SOFF in QLD.

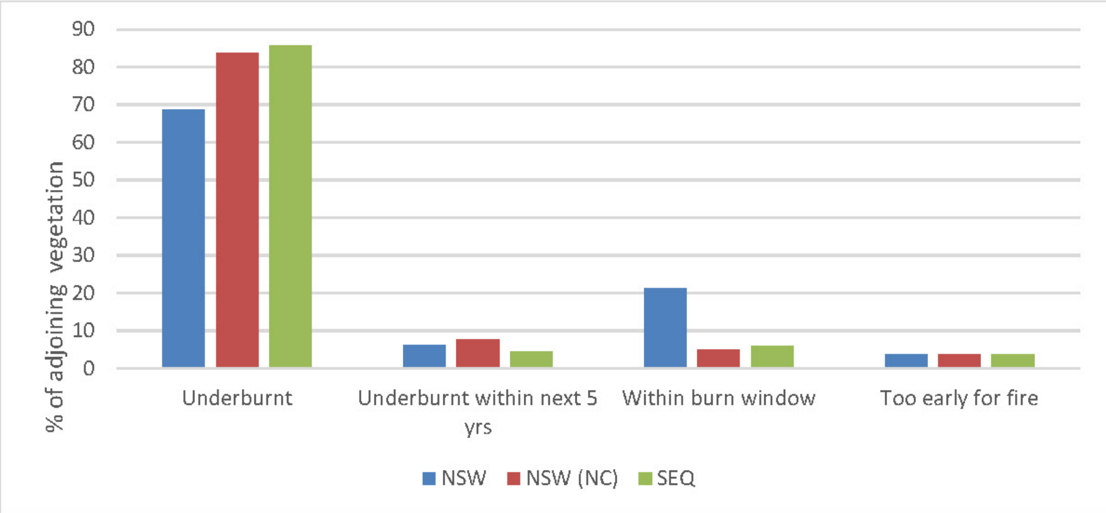

Figure 2. Fire threshold status for fire-dependent vegetation adjoining Swamp Oak remnants in the northern rivers region of NSW. Fire interval guidelines include NSW (Kenny *et al.* 2004), NSW North Coast (NC) (Watson 2001, 2006; Tierney & Watson 2009) and SEQ Planned Burn Guidelines (NPRSR 2013).

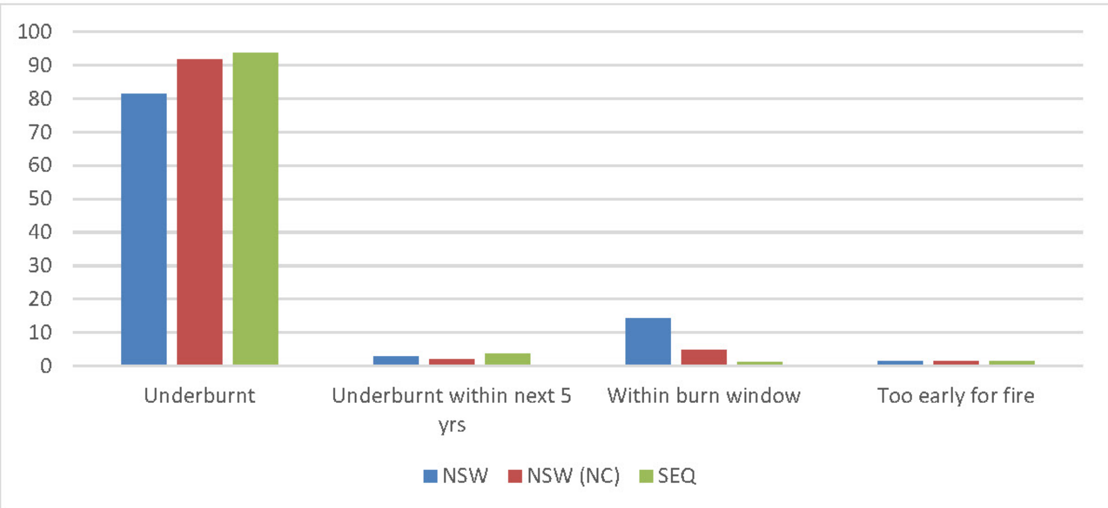

Figure 3. Fire threshold status for all Swamp Oak remnants in the northern rivers region of NSW. Fire interval guidelines include NSW (Kenny *et al.* 2004), NSW North Coast (NC) (Watson 2001, 2006; Tierney & Watson 2009) and SEQ Planned Burn Guidelines (NPRSR 2013).

4 ECOLOGICAL CONSEQUENCES OF LOW FREQUENCY FIRE

Low frequency fire is an important threatening process affecting open forests generally, and is attributed to a wide range of detrimental ecological consequences in Australia and globally (e.g. Moreira 2000; Woinarski, Risler & Kean 2004a; Bond, Woodward & Midgley 2005a; Nowacki & Abrams 2008; Parr, Gray & Bond 2012; Tasker *et al.* 2017). Given the typically open forest structure of SOFF, <u>a precautionary approach would assume that low frequency fire will have similar ecological consequences in this community unless strong evidence demonstrates otherwise.</u>

To date, low frequency fire has been explicitly attributed to a range of consequences in SOFF (NPRSR 2013; DSITI 2014), including:

- Loss of open structure (i.e. canopy closure)
- Loss of graminoid ground layer
- Increased presence of weeds such as lantana.
- Increased fire intensity from elevated fuel loads, leading to 100% leaf scorch and death of canopy swamp oak trees.

Across open forests generally, low frequency fire is attributed to a range of consequences including:

1. Structural change and ecosystem displacement
2. Localised decline and extinction of open-forest flora species
3. Localised decline and extinction of open-forest fauna species
4. Reduced flammability and reinforcement of further rainforest invasion

4.1 Structural change and ecosystem displacement

Changes in the structure and distribution of fire-dependent vegetation communities due to fire exclusion is a global phenomenon, being particularly well documented in North America (e.g. Heinselman 1973; Abrams & Nowacki 1992; Nowacki & Abrams 2008), Africa (e.g. Manders, Richardson & Masson 1992; Joubert, Smith & Hoffman 2012) and Australia (e.g. Jackson 1968; Fensham & Fairfax 1996; Bowman *et al.* 2013; Stanton *et al.* 2014a; b).

Open-forests and woodlands are characterised by an 'open' tree canopy, above an understorey plant community of graminoids, forbs and shrubs (Specht and Specht 1999; Bond and Parr 2010; Kirkman and Mitchell 2006)(See Appendix A). These understorey plant communities contain the majority of ecosystem plant diversity, provide key forage, shelter and nesting habitat for fauna, and the fine fuel needed for frequent fires to maintain ecosystem structure and diversity (Veldman *et al.* 2015; Murphy *et al.* 2016). In these systems, regular disturbance (fire, herbivory) promotes high understorey density and richness, by preventing competitive exclusion of grasses, forbs and shrubs by taller woody plants (Ratajczak *et al.* 2012; Woinarski *et al.* 2004a). Fire periodically reduces mid-storey cover and regulates the rate of tree population recruitment into the canopy. Without disturbance however, tree cover progressively increases, reducing light, water and nutrient availability for understorey plant species (Close *et al.* 2009; Specht and Morgan 1981; Jackson *et al.* 2007; Hart *et al.* 2005). The relationship of diminishing light and ground flora loss is illustrated in Figure 2.

2.4 Open forest structure

The typical open forest structure of many occurrences of CCPF (i.e. open canopy and dense heathy understorey; Appendix A) indicates that CCPF shares similar relationships to fire, as those of open forests generally. It is well established that open forests typically require fire to maintain their open canopy structure (Swain 1928; Jackson 1968; Bowman 2000a; Gammage 2011; Murphy & Bowman 2012). Without fire, canopy closure can occur through increased mid-storey density, primarily through recruitment and growth of bird-dispersed, fire-sensitive rainforest trees (Appendix A) that may ultimately cause a biome shift to closed canopy rainforest. Such changes are known to occur in CCPF (NPRSR 2013; DSITI 2014, A. Baker, Pers. Obs.). The other key structural feature of open forests, common also in CCPF, is a dense ground layer of flammable graminoids, ferns and forbs (DOE 2017). In open-forests this flammable ground-layer is crucial to facilitating the regular fire needed to maintain open canopy structure, but is often lost if fire exclusion allows canopy closure to shade it out (Murphy *et al.* 2010; Hoffmann *et al.* 2012a; Bowman *et al.* 2013; Butler *et al.* 2014a).

3 THE PREDOMINANCE OF LOW FREQUENCY FIRE IN CCPF

Analysis of fire history records (NPWS 2019) using the methods of (Baker & Catterall 2015) indicate that throughout much of its extent, CCPF is predominantly affected by *low-frequency fire* (i.e. beyond recommended thresholds for biodiversity conservation). For example, in the northern rivers region of NSW, comparison of fire history data with both statewide and regionally-specific fire interval guidelines show that 45-59% of CCPF is underburnt, 30% is ready for fire, while only 11% is not yet ready for fire (Figure 3).

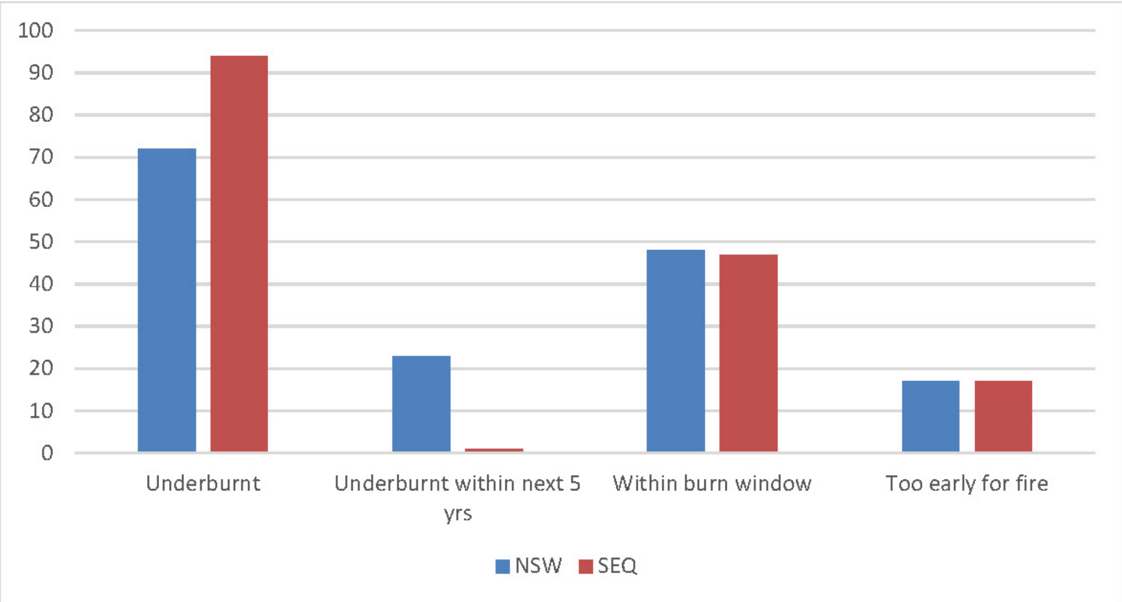

Figure 2. Fire threshold status for Coast Cypress Pine Forest in the northern rivers region of NSW. Fire interval guidelines include NSW (Kenny *et al.* 2004) and SEQ Planned Burn Guidelines (NPRSR 2013).

4 ECOLOGICAL CONSEQUENCES OF LOW FREQUENCY FIRE

The vital attributes (Noble & Slatyer, 1980; Noble & Gitay, 1996) of *Callitris columellaris* indicate that it is likely to become locally extinct with long-term fire-exclusion. These include: i) having a short-lived seed bank (transient or lost at senescence of plant), and ii) being intolerant of competition, thus only establish and grow after disturbance (e.g. fire). This point is particularly significant given *C. columellaris* is the defining dominant species of the TEC.

Additionally, the *NSW Flora Fire Response Database* (OEH, 2014 and references within) states that at least ten species listed as characteristic of the TEC (DECC, 2009) are likely to become

Appendix F. Extract from Baker 2019d - Fire Interval Status: Grey Box Grey Gum Fire TEC

that rather than being a stable community, this community configuration represents a brief point in time. And that over coming decades, these sites will transition to a closed forest state due to the suppression of once regular fire, which historically was crucial in maintaining the open-forest state. Consideration of the likely long-term vegetation dynamics with continued fire suppression raises very difficult questions for this community, most notably: *what mechanism (if not regular fire) prevents the rainforest trees displacing the shade-intolerant ground layer flora, and ultimately the dominant Eucalypts in the canopy?* While rainforest mid-storey development is celebrated in northern NSW (due partly to its utility in protecting forest from logging operations), it is recognised as a threat to the long-term viability of similar open-forest in far north Queensland, prompting these forests to be listed as threatened ecological communities due to this threat.

3 THE PREDOMINANCE OF LOW FREQUENCY FIRE IN GBGG

Analysis of fire history records (NPWS 2019) using the methods of Baker & Catterall (2015; Table 3) indicate that GBGG is predominantly affected by *low-frequency fire* (i.e. beyond recommended thresholds for biodiversity conservation). Comparison of fire history data with both statewide and regionally-specific fire interval guidelines (grassy sub-formation; see section 3.1 below) show that 52-96% of GBGG is underburnt (Figure 1). Even a more conservative analysis using fire interval guidelines for rainforest understorey (Figure 2) shows that 82-84% of GBGG is now within the appropriate burn window for applying fire.

Low-intensity burns by graziers are often not included in the fire history records, and it is likely that these fires occasionally enter some GBGG remnants which retain a grassy ground layer sufficient to carry fires in mild weather conditions - typically mild evenings in late winter. However, such fires are unlikely to affect remnants which have lost the grassy ground layer due to recent logging disturbance or suppression beneath encroaching Lantana or rainforest pioneers and vines. The fire age classes indicated by the analysis (Figure 1; Figure 2; i.e. most remnants are long-unburnt) closely aligns with the disturbance assessments undertaken as part of the survey to define GBGG (52 sites).

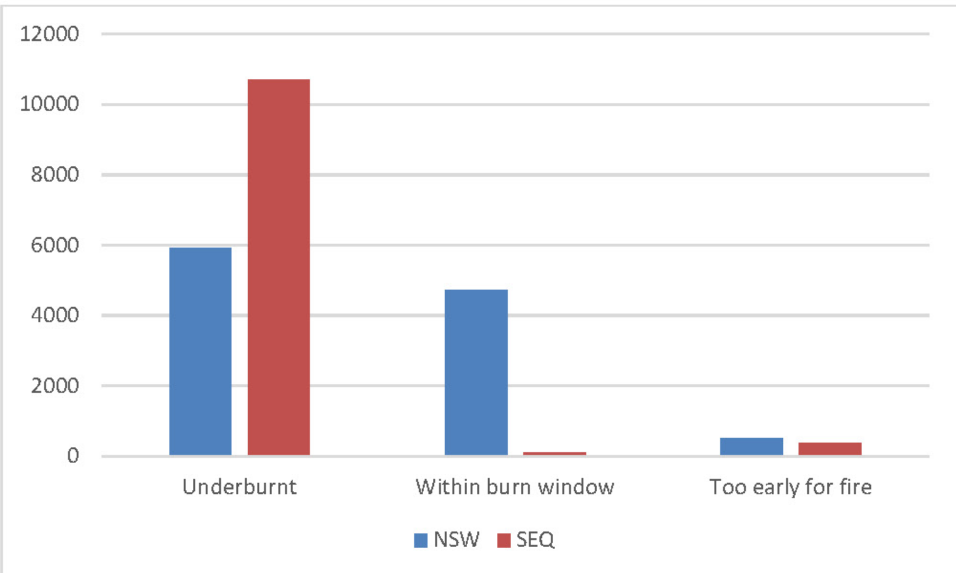

Figure 1. Fire threshold status for Grey Box – Grey Gum Forest (grassy sub-formation). Fire interval guidelines include NSW (Kenny *et al.* 2004) and SEQ Planned Burn Guidelines (NPRSR 2013).

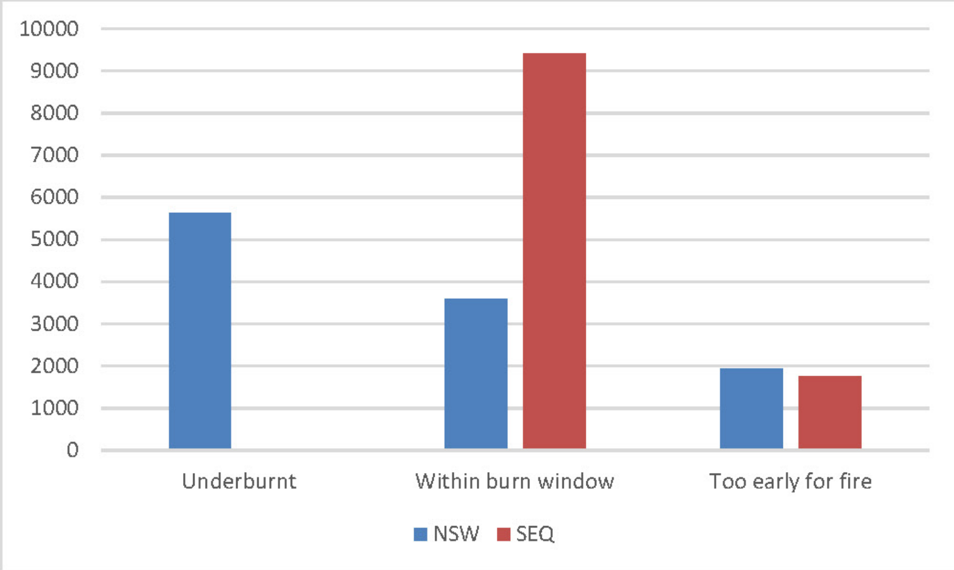

Figure 2. Fire threshold status for all Grey Box – Grey Gum Forest (rainforest sub-formation). Fire interval guidelines include NSW (Kenny *et al.* 2004), NSW North Coast (NC) (Watson 2001, 2006; Tierney & Watson 2009) and SEQ Planned Burn Guidelines (NPRSR 2013).

3.1 RECOMMENDED FIRE-FREQUENCY IN GBGG

The recommended fire-intervals for GBGG vary with formation and jurisdiction (Kenny, Sutherland, Tasker, & Bradstock, 2004; NPRSR, 2013; Table 3).

Table 3. Recommended fire intervals for GBGG in NSW & QLD (Kenny *et al.* 2004; NPRSR 2013).

Jurisdiction	GBGG Equivalent	Recommended interval
Southeast QLD Bioregion (extending into NSW)	Wet Open Forest (grassy understorey)	3-6 years
	Wet open Forest (rainforest understorey)	20-? years
NSW (statewide)	Wet Sclerophyll Forest (grassy)	10-50
	Wet Sclerophyll Forest (shrubby)	25-60

The use of the regional SEQ guidelines in GBGG is supported by several reasons. Firstly, the use of regional, rather than statewide guidelines is recommended by the Northern Rivers Regional Biodiversity Management Plan (DECCW 2010) and the NPWS Fire Management Manual (OEH 2014).

Secondly, the SEQ guidelines specifically consider the role of interspecific competition and succession in long-unburnt vegetation, which is particularly relevant in fire-excluded patches of GBGG (See Section 2 & 4 for discussion of related issues). Conversely, the guidelines of Kenny *et al.* (2004) do not consider competition and succession, but consider only the vital attributes of each species in isolation (e.g. age to reproductive maturity, lifespan and longevity of seed banks).

Structural change following fire exclusion is accelerated in regions of high rainfall and temperature (Watson 2006, Hoffman *et al.* 2012), and is likely to be of key importance in the highly productive landscapes of the Northern Rivers Region (Watson 2006). Research in related Eucalypt forests regionally supports the use of the 3-6-year interval in GBGG, where a dense mid-storey of rainforest and wattle trees has been found to