Good Fire - Healthy Country

Supporting Information for *Good Fire Restoration Plans*

FIRST EDITION

June 2023

wildsite ecological services
JAGUN ALLIANCE ABORIGINAL CORPORATION
ZERO EMISSIONS BYRON
inGRAINED FOUNDATION
BYRON SHIRE COUNCIL

Jingii wala blaganmirr (Welcome Everyone)

Ngalii-ngaa naa jaguun gunuu djanda mandii nguthung garra guuriaabun, beehing, nguubuu-gan (We acknowledge Country – our elders past present and future)

Ngalii-ngaa binung-garri jerrd muugaa guuway gulgii-wen (We know big storms bring change)

ngalii maanal ngambaa gulgii-wen buuyawan gawarii-gaa (We get ready for more change to come)

Ngalli-ngaa bilaan buuwiiaan, gwang, buubaan, jan-gany webrrd muunaa gali maadj butherun (We learn from wind, rain, flood, lightning, hail, or fire – they teach us stories)

Ngalii-ngaa wala-wala guuriilaa wuuyun-girr (We share old ways into the new)

Ngalii-ngaa nyaagii gaany ba-aarn nguubuugan (We need these ways now and for our future)

Ngalii ngaa garima lee la jaguun, jaguun garima mebeerrd (We care for Country, as Country cares for us)

Ngalli ngaa naa gannga la (We hope you understand)

Bugle bee wala-wala (We thank you for the opportunity to share)

Statement and Language by Uncle Rick Cook, Marcus Ferguson and Oliver Costello.

Acknowledgement of Country

We acknowledge the Bundjalung nation as the Traditional Custodians of this place. We recognise the lore and authority of Elders past and present. We respect their continuing connections and responsibilities to Country.

Citation

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Front Cover: Eco-cultural burn in dry sclerophyll forest at Broken Head.

Contents

Arakwal Bumberlin Traditional Elder Norm Graham caring for Country with fire at Broken Head.

1 Background

This document provides background information to support *Good Fire Restoration Plans*, which are streamlined action plans that provide fire practitioners and landowners with guidelines and actions to restore Good Fire on individual properties. This document, and the associated Good Fire Restoration Plan template, have been prepared to support organisations develop and implement multi-property fire-restoration projects across the Northern Rivers region. These documents were prepared by a cross-cultural collaboration forged by the Firesticks Initiative to bring back Good Fire Country, in partnerships with Wildsite Ecological Services (Andy Baker), Jagun Alliance Aboriginal Corporation (Oliver Costello, Richard Geddes, Marcus Ferguson) and Zero Emissions Byron (ZEB, Wren Mclean) with generous funding from the inGrained Foundation.

The restoration of Good Fire provides a vital pathway to restore and conserve biodiversity, continue Aboriginal cultural practices and connection to Country, improve community bushfire safety, and restore dormant carbon sequestration pathways.

1.1 Bringing together ecological and cultural perspectives

The desire to restore Good Fire arises from two different but overlapping community perspectives: *traditional cultural practice* and *modern ecological restoration*. At their core, both perspectives share the overarching vision of *looking after Country.* However each perspective also has its own system of values and protocols.

As a **traditional cultural practice**, *Good Fire* provides opportunities to care for and connect to Country. This is a continuing practice followed by the land's traditional custodians who do not seek to own things or land, rather create new ways, guided by our old ways, to care for the lands and sea, and all the waters that pass through our Country. We burn because the lightning taught us the lore of fire. By repeating lightning's practice of Good Fire across the lands, the waters will flow clear, and the air will be fresh as it is filtered by the leaves on the trees. Good Fire brings purity when it is the right fire for that Country. Thousands of generations of families have lived and passed through this country, shaping and building it in better ways through their practice of caring for Country. Some move with time – others move across the lands and waters –similar to the way fire moves like a snake or other times an eagle. Always looking to strike down the next ignition point on the journey to keep fuel to drive the motion of its life. Consuming the fuel as it wanders or runs and jumps along the energy lines in the landscape. We can shape some of these lines, but many are shaped for us by the wind and the rain while others grow and change with time. That's how we can work with fire, by influencing where fire goes and how often and what then grows in these places. This relationship between these forces teaches us protocols of respect for that beyond ourselves in the present tense, forces with which we share a common good. This is critical to help provide balance in the exchanges and a pathway to give back allowing greater respect for the values of all. Fire teaches us lore and we must follow the local protocols taught by the Country- all things that we do or don't see that are the fabric of that place, giving it identity.

From an **ecological restoration perspective**, *Good Fire* also provides opportunities to care for and connect to Country, through the restoration of degraded ecosystems and the conservation of plant and animal diversity. Its protocols are defined by environmental guidelines, policy and legislation that seek to protect and restore these values and are largely based on an evolving ecological science.

To honour both perspectives, *Good Fire Restoration Plans* and this supporting information document seek to support the restoration of Good Fire consistent with cultural and ecological values and shared protocols. See **Sections 3 & 6**.for more on cultural and ecological values and shared protocols.

"Country still holds her stories and we each, no matter what our culture or race, have a role to play in keeping her healthy and strong"

Zena Cumpston, Barkandji Researcher
First Knowledges Plants: Past, Present and Future 2022

1.2 Why do Good Fire Restoration Plans need supporting information?

The restoration of *Good Fire* is a newly emerging aspect of land management in this region, and so the diverse relationships between fire, biodiversity and Bundjalung culture are often poorly understood by conventional practitioners, landowners and the general public. To address this, this document provides background information to provide deeper understanding of the fundamental importance of fire in Bundjalung culture and the conservation of fire-dependent biodiversity. This background information is provided in this separate document to avoid cluttering the streamlined action plans, and is intended to provide context to:

- assist curators or creators in preparing *Good Fire Restoration Plans (including methods for property assessments;* **Appendix B***)*; and
- help igniters/initiators (practitioners) and custodians (landowners) of *Good Fire Restoration Plans* to better understand plan rationale, guidelines and actions.

The importance of stakeholder knowledge to the success of projects seeking to restore Fire Country is supported by interviews with senior ecological restoration practitioners in the Northern Rivers [1,2] (**Figure 1**), which found that effective fire restoration relies on four key factors, including:

1. an *awareness of the value* of fire Country (i.e. open ecosystems and their biodiversity)
2. an *awareness of threats* to fire country that come from excluding Good Fire
3. the *ability to recognise the decline* of fire-excluded fire country
4. knowledge of available solutions to restore *Good Fire*.

This document aims to increase stakeholder knowledge and awareness in these areas four areas.

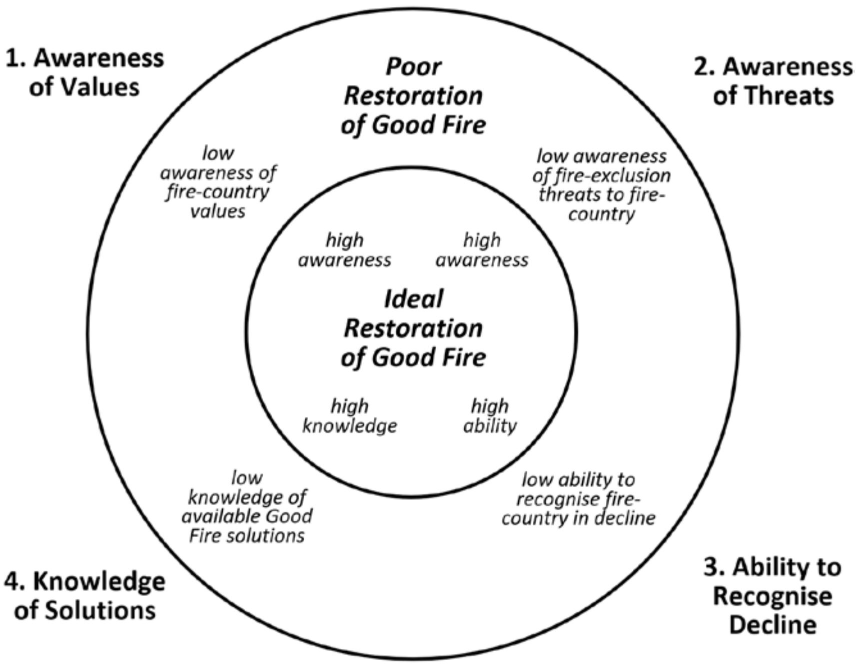


Figure 1. *Key factors that influence the success of restoring Good Fire (appropriate fire regimes) in Fire Country (fire-dependent vegetation). Restoration success is increased when conditions are high for all factors (inner circle); reduction of any one factor (outer circle) can reduce the likelihood of fire exclusion being identified as a threatening process and appropriate management solutions being recommended* [2].

1.3 Why use a plan template?

Given that the revival of *Good Fire* as a land management tool is re-emerging in this region, there has been limited opportunity for fire and restoration practitioners to develop a rigorous assessment and planning approach. To address this, the template provides authors with a targeted and consistent approach for assessing and communicating altered fire regime issues relevant to the region. The need for a template is supported by a recent review of over 60 ecological restoration and management plans in Byron Shire [3]. The study found that explicit prompts to identify and address fire exclusion are key to ensuring Plans effectively manage altered fire regimes and conserve fire-dependent biodiversity.

2 What is Fire Country?

From a **Bundjalung cultural kinship perspective**, *Fire Country* is where fire belongs to the plants. They teach the lore of fire through their flowers, seeds, leaves, bark and roots. The animals that belong there know lots of fire stories, taught over time in the same way the plants learnt – different every time. Not all plants like fire and many that do have an intense relationship and are constantly waxing or waning with fire. Fire tends to boom or bust, so balance must be found to sustain longer periods of abundance in growth and diversity of the life cycles in a place. Not enough fire for some can be too much for others and vice versa, too much fire for some can be not enough for others. Learning this the hard way plants have evolved with fire dependence and sensitivities to create complex and diverse relationships. People have learnt these stories and relationship through kinship. Fire country teaches us the kinship of fire lore.

Figure 2. *Bundjalung fire practitioners applying cultural fire to dry sclerophyll forest in Broken Head.*

From an **ecological perspective**, *Fire Country* includes those ecosystems which are prone to burning and which need periodic fire to maintain their structure, composition and their place in the landscape. In the Northern Rivers, *fire country* includes all open forests (i.e. Eucalypt, Brush Box and Paperbark forest), heathlands and native grasslands (**Figure 3**). Conversely, *no-fire country* includes those parts of the landscape that are protected from regular fire, usually resulting in the development of fire-sensitive rainforest (See **Box 1**).

Figure 3. *Examples of fire-country ecosystems in Byron Shire: a) grassy clay heathland, b & c) heathy dry open forest and d) forested wetlands.*

2.1.1 Ecological structure and function of Fire Country

In high rainfall regions in Australia, fire frequency is the main factor controlling the distribution of rainforest and open ecosystems [4], and there is increasing evidence that each ecosystem type modifies fire frequency to maintain their place in the landscape [5,6]. The open canopy of open ecosystems, allows high light to promote the growth of a flammable understorey that can carry regular fire, thereby maintaining an open canopy through periodic scorching (**Figure 4**). Conversely, the closed canopy of rainforests shades out flammable ground-layer vegetation, thereby suppressing fires that could scorch openings in the canopy. This model illustrates the ideal reference *structure* and *function* of open ecosystems, with key indicators of ecosystem resilience being i) an open canopy, ii) a dense ground layer and iii) regular fire. Key indicators of open-ecosystem decline are i) a closed canopy and/or midstorey, ii) a sparse ground layer and iii) fire suppression. Modern ecological terms for the dichotomy between fire country and no-fire country, include *open ecosystems* and *closed ecosystems*; *fire-dependent* and *fire-sensitive* ecosystems; *flame forests* and *rainforests* [5,7,8].

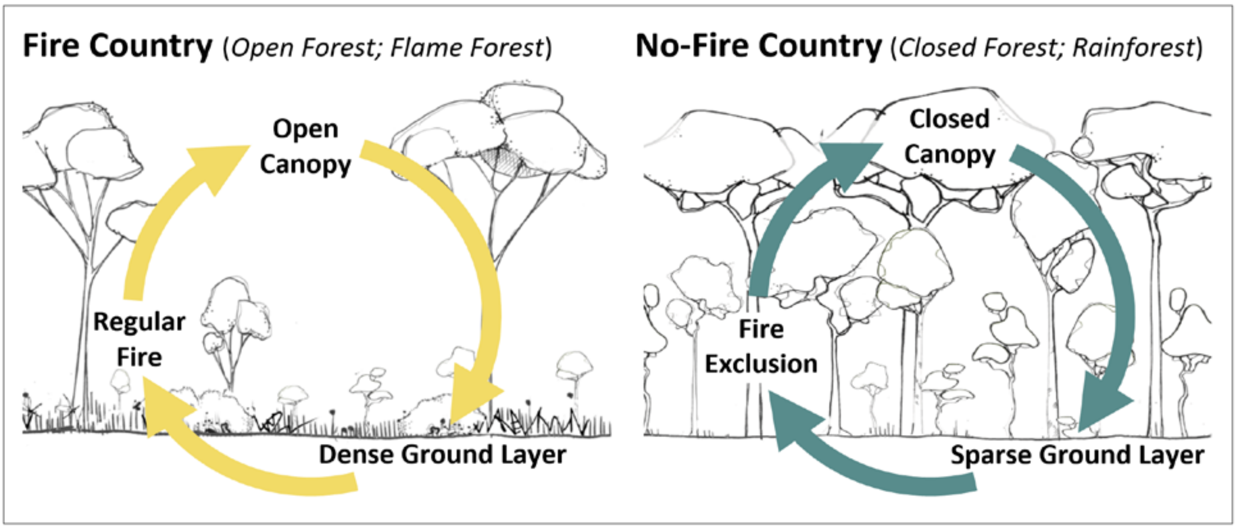


Figure 4. *The contrasting structure and function of open and closed forests. Open forests have an open canopy that allows ample sunlight to fuel the growth of a dense ground layer, which in turn can carry regular fire and prevent canopy closure by limiting the number of saplings that reach the canopy. Conversely, closed forests have a closed canopy that intercepts sunlight, resulting in a sparse ground layer that is unable to carry regular fire, so maintaining the closed canopy in the absence of crown scorching.*

2.1.2 A note on wet sclerophyll forests with a rainforest subcanopy

While the reference structure and function of fire country shown above is easy to recognise in open forests with a heathy, grassy or ferny ground layer, it is less clear in wet sclerophyll forests with a dense rainforest subcanopy, now common across the region. However, there is increasing evidence that in many areas this rainforest understorey may have developed in the absence of regular fire since colonisation [9–11] and that historically the boundary between grassy/heathy open forest and closed rainforest occurred abruptly (< 50m) [12,13]. For example, Bernard O'Reilly writes of his experience of the Border Ranges-Lamington landscape in the early 1900's of the *'sudden change from open country to the rainforest',* describing the boundary between grassy open forest and rainforest as a *'high green wall of forest',* where *'there is not a gradual merging of kinds'*, but *'a sharply drawn line which neither may cross'* [9]. Today, most open forests in this region have a well-developed midstorey or subcanopy of rainforest, blurring the distinction between open- and closed-forests.

Irrespective of their historical structure and fire regimes, it is often not possible or desirable to introduce fire into forests with a rainforest sub-canopy under planned burn conditions and it is likely that restorative fire will only ever penetrate under extreme conditions [11]. However, Good Fire is desirable to maintain wet sclerophyll forests which retain a dense matrix of flammable ferns, graminoids and scattered heathy shrubs beneath scattered rainforest trees and shrubs (See **Figure 5**). In these forests, rainforest species persist by resprouting between fires, but are prevented from forming a dense shady midstorey that would eliminate the ground layer, by periodic fires carried by the flammable ground layer.

Figure 5. *Wet sclerophyll forest with a fern/shrub groundlayer beneath scattered rainforest trees at Tanglewood on the Tweed coast. Fires occur in this forest about every 5-15 years, which helps maintain a diversity of rainforest plants in the midstorey, while also maintaining a dense flammable ground layer consistent with reference open forest structure and function.*

Good Fire benefits rainforest biodiversity

The rainforests of Northern Rivers are of **global conservation significance** and include unique ecosystems and species of plants and animals that are found nowhere else on earth. Rainforests are fire-sensitive and thrive in those parts of the landscape that are sheltered from regular fire. Despite this, *Good Fire* can still play a crucial role in the protection and maintenance of rainforest biodiversity.

Firstly, *Good Fire* can help protect rainforests from severe wildfires by carefully reducing fuels in adjacent areas of open forest. *Good Fire* maintains the equilibrium of the rainforest and open forest boundaries. It has long been used by Bundjalung people to protect fire-sensitive values, and it will be an increasingly valuable strategy for protecting rainforests from wildfire threats predicted with climate change (e.g. King et al. 2008) [14].

Secondly, *Good Fire* is crucial for threatened *rainforest* animals that also need nearby areas of *non-rainforest* habitat to survive. For example, the Queensland Blossom Bat and the Parma Wallaby both sleep in the rainforest by day, but emerge into heathland or open forest at night to find foods not found in rainforest. Without Good Fire to maintain complimentary open habitats, these rainforest animals will gradually disappear from the landscape.

Good Fire is crucial for non-rainforest biodiversity

At the other end of the spectrum, Good Fire is needed to curb rainforest pioneers from invading and degrading open ecosystems. For some readers, the concept of rainforest plants being unwelcome invaders in non-rainforest ecosystems may be new and challenging. However, from the perspective of open-ecosystem plants and animals, the invasion of rainforest pioneers into their habitat is often catastrophic, and is arguably the biggest threat to the valuable open-ecosystem biodiversity of the region.

Good Fire Restoration Plans acknowledge the enormous conservation value of rainforest, and strive to conserve *both* rainforest *and* open-ecosystems throughout the Northern Rivers. Currently however, conservation investment, training and policy are heavily skewed towards rainforest biodiversity, resulting in widespread efforts since the 1990s to exclude fire from open-ecosystems for the benefit of rainforest species [3]. Such efforts are driving the localised extinction of open ecosystem plants and animals throughout the Region. *Good Fire Restoration Plans* seek to redress this bias by restoring historical fire frequency in fire-dependent ecosystems so that future generations may enjoy the precious biodiversity at both ends of the fire spectrum.

Box 1. *Good Fire & Rainforests.*

3 The Value of Fire Country

3.1 Cultural value of Fire Country

Fire country has many values to many kin. Where ever you go in fire Country you see different and similar entities. All these entities have values and relationships that relate to fire in that Fire Country. That's why when we learn to burn fire Country we learn the cultural values. What are the plants and animals that belong there and what are their stories. Their stories are the dreamtime. They are the relationship's that forged through creation together. Why they relate to each other in that way where they are, is because in different places the stories of the same ancestors can be different in places and the relationship can change over time. Differing environmental and social systems create diversity in fire country. Fire Country is diverse because it has been shaped by nature and nurture, and the shapers have diverse values and practices. Burabi the Koala belongs to Fire Country, they love the leaves of the tall open trees and can then see too far to go until they get there. They live on the old peoples pathways, same as old Emu. Emu looks out across to see which way and how far. They warn the rest of their kin and guide them across the pathways from the sea to the peaks across the valleys and to the other side and beyond. Wattle and tea trees don't go too far, but yet stretch out along their journeys of fire in the same way that the gum holds the fire so long. Caught up in the intense relationship, fire breeds trees and trees breed fire and along the path they go. Wagun the Brush Turkey learnt fire the hard way and will never forget that lesson. Marked with the knowledge of bad fire. They are born with that knowledge and spend every day from the crack of dawn cleaning up and moving on.

3.2 Ecological value of Fire Country

We are all aware of the enormous ecological value of our rainforests (no-fire country), but few people realise that the Eucalypt Forests of NE NSW are also of global conservation significance [15] and are recommended for listing as a world heritage area [16]. The main ecological values of Fire Country can be summarised as four key values, as outline below.

1) **Open ecosystems provide unique habitat.** Around 40% of the plant species and 75% of the animal species of the Northern Rivers rely on open ecosystems for resources that are not provided by rainforest. Habitat features unique to fire country include:
   - Tree hollows of Eucalypts (and related genera) that provide crucial roosting & nesting resources for arboreal mammals, insectivorous bats, parrots and forest owls
   - An open, sunlit structure to support rich ground-layer communities of shade-intolerant grasses, sedges, ferns, herbs and heathy shrubs
   - Dense ground layer plant communities that provide nesting, shelter and foraging habitat for small mammals, ground nesting birds, frogs and invertebrates
   - Seasonally abundant nectar of Eucalypts and Paperbarks crucial for nomadic nectivorous bird and flying-fox species
2) **Open ecosystems are ancient**. Like rainforests, many flora species in open ecosystems are of Gondwanan lineage and fossils reveal that Eucalypts, Banksias and their relatives have co-existed with fire for 50-90 million years [17,18], probably sharing the landscape with dinosaurs. Ultimately, open ecosystems have co-existed and been shaped by fire for over 430 million years [19].
3) **Open ecosystems have been over-cleared & under-reserved.** The vast open forests that once dominated the region's floodplains and north-facing slopes were disproportionately cleared to gain access to the most productive agriculture lands. Few of the small, scattered remnants which survive today, are protected in conservation reserves.
4) **Open-ecosystems are extremely fragile and difficult to restore.** Open ecosystems are typically resilient to fire, but the removal of regular fire triggers their decline and ultimate collapse. And unlike bird-dispersed seeds of many rainforest plants, that can readily recolonise cleared lands, most open forest plants have very poor seed dispersal and require human help to recolonise former habitat.

3.2.1 Threatened Species Values

The open ecosystems of Northern Rivers provide crucial habitat for numerous threatened plants and animals and also include a number of endangered ecological communities. In Byron Shire for example, around 75% (59) of all threatened fauna species use open ecosystem habitats, with 55% (43) being entirely dependent on open-ecosystems (**Figure 6**). In contrast, only 25% (20) of threatened fauna are restricted to rainforest and/or wet sclerophyll forests with rainforest understorey.

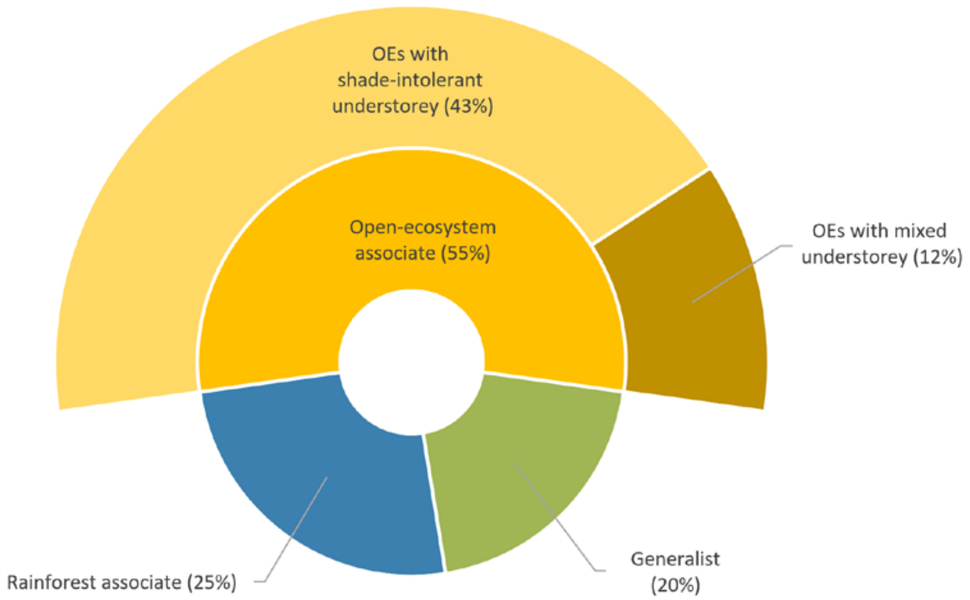


Figure 6. Habitat associations of threatened fauna recorded in Byron Shire. *Rainforest associates are restricted to rainforest and wet sclerophyll forest with a rainforest understorey; open-ecosystem associates prefer sclerophyll forests and/or treeless ecosystems; generalists use both open-ecosystem and rainforest habitats.*

Although 76% (54) of threatened flora species in Byron Shire are rainforest associates, open ecosystems still provide important habitat for the remaining 24% (17), including 14% (10) that are restricted entirely to open ecosystems. Examples of threatened species restricted to open ecosystems in Byron Shire are shown in **Figure 7**.

Open ecosystems also include a number of endangered ecological communities (*NSW Biodiversity Conservation Act 2016*) in Northern Rivers, including:

- *Byron Graminoid Clay Heath*
- *Coastal Cypress Pine Forest*
- *Grey Box—Grey Gum Wet Sclerophyll Forest*
- *Subtropical Coastal Floodplain Forest*
- *Swamp Oak Floodplain Forest*
- *Swamp Sclerophyll Forest on Coastal Floodplains*
- *White Box - Yellow Box - Blakely's Red Gum Grassy Woodland*
- *White Gum Moist Forest in the NSW North Coast Bioregion*

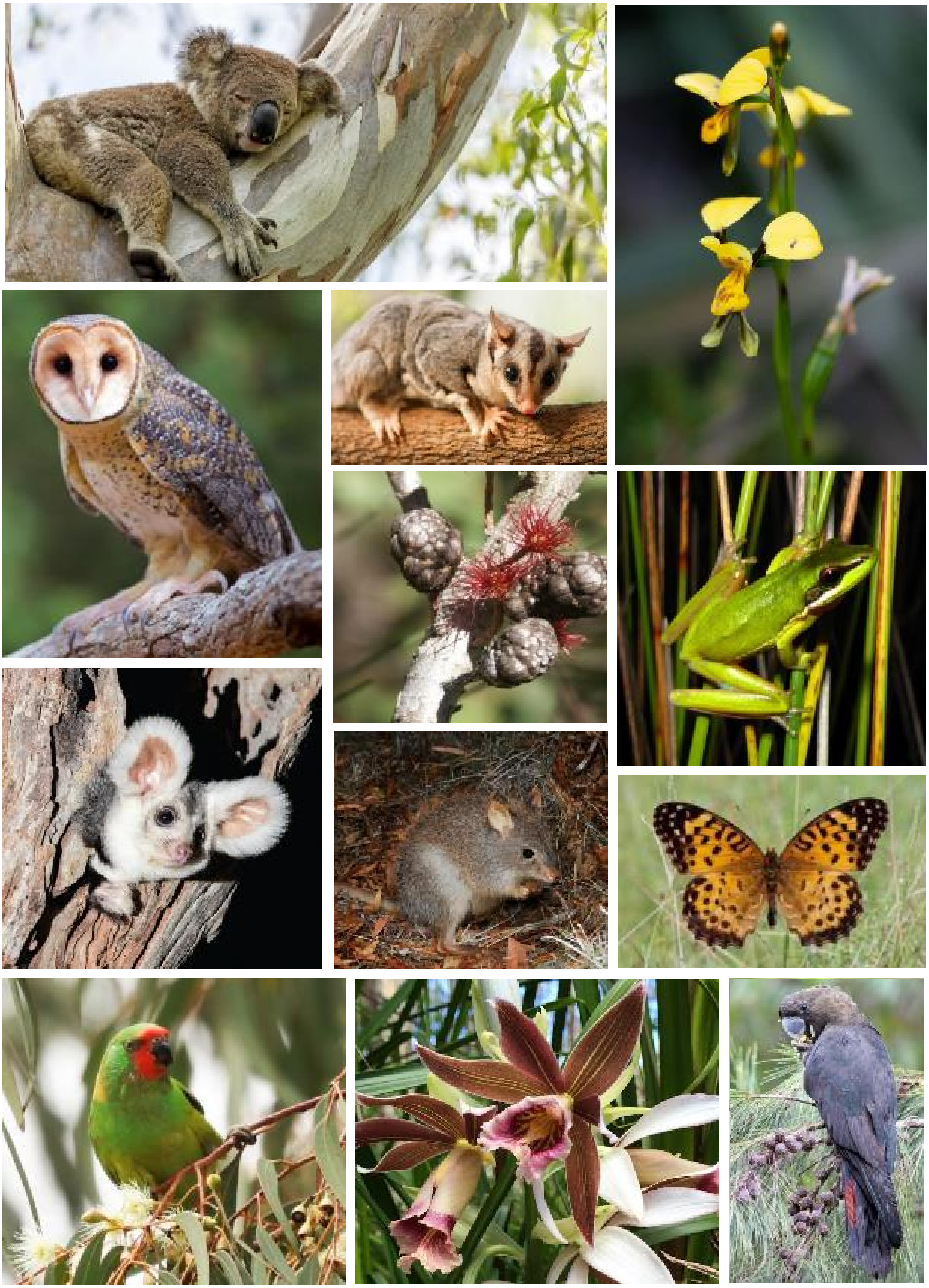


Figure 7. Examples of threatened species restricted to open ecosystem habitats in the Northern Rivers.
Species from top left: Koala (Australian Koala Foundation), Byron Bay Diuris (Andy Baker), Masked Owl (Marc Anderson), Squirrel Glider (Canva NFP), Allocasuarina thalassoscopica, Olongburra Frog (Katrin Lowe), Greater Glider (Josh Bowell), Rufous Bettong (Eric Vanderduys), Laced Fritillary (L Matthews), Little Lorikeet (David Ongley), Southern Swamp Orchid (Andy Baker), Glossy Black Cockatoo (Duade Paton).

4 What is Good Fire?

Good Fire is fire that enhances the health of the land and its people. At the time of European colonisation, Aboriginal and lightning fires were crucial elements throughout our landscapes. Today however, landscape fire has been largely extinguished, priming long-unburnt country to be ravaged by severe wildfires during prolonged droughts. This profound shift in landscape fire is a major threat to biodiversity and severs a key pathway for Aboriginal custodians to connect with and care for Country. Therefore, the restoration of *Good Fire* provides opportunities for all people to heal and reconnect with Country and is crucial if we are to conserve the plants and animals that depend on our Eucalypt forests, heathlands and grasslands.

4.1 Cultural fire

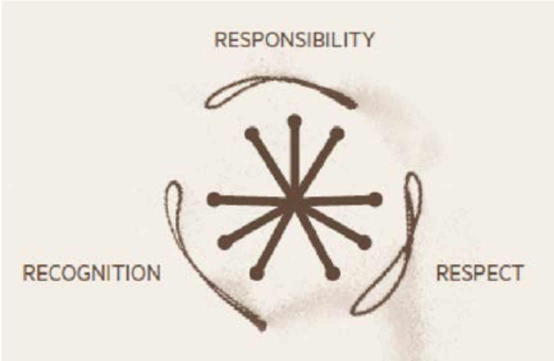
Fire is known by many terms and in many languages. Cultural fire describes practices used by Aboriginal people to enhance the health of land and its people. Cultural fire means different things to different people. It is ceremony to welcome people to Country or is as simple as a campfire around which people gather to share, learn, and celebrate. It can include burning (or preventing burning) for the health of particular cultural values, people, plants, animals and places.

Cultural fire is Good Fire, and the ways Aboriginal people burn for Healthy Country through cultural lore and kinship. It is the cultural practice of First Nations people in many parts of the world. To maintain the cultural integrity of these practices they must be led or guided by Traditional Custodians with local knowledge, connections and authority. Healthy Country is critical for maintaining the kinship of the land and people connected to it. Traditionally local custodians regularly applied cultural fire to protect and improve the cultural resources and values to ensure safe and abundant landscapes. These practices were originally learnt from the naturally occurring fire regimes which can be both detrimental or beneficial to species and habitats. By learning the ways fire is good and bad, people learnt and shared knowledge on how to harness fire to shape the landscape. People evolved to carry fire for their own good and that of their kin. The diversity of Country shaped Aboriginal people's values and in turn these values shaped the land, which means it is critical to understand the local cultural values of Country before applying fire. When burning Country there are always winners and losers in relation to the fire regime. Cultural fire is about understanding that kinship between species and places to allow the ancestors of place to grow and regenerate, while adapting as systems interact and evolve.

Good fire is healthy fire for that Country. Cultural fire is Good Fire that brings the fire and water mob along, continuing to guide in the light of the next generation as they move through the Country and beyond.

Good fire is maintaining healthy grassy forest and Cultural fire supports the pathways to allow access and to provide habitat for culturally significant species:

- Open Country with grasses, seeds and fruits for insects, birds and mammals.
- Protect our elder trees as they have an important role and provide resources, but as there may be more younger ones, we may sometimes need to maintain a balance with other plant species.
- Protect and/or rejuvenate Geebungs, fruiting and flowering nectar plants, some will get burnt, but others will come back.
- Protect and enhance Bilang Forest Oak (Allocasuarina torulosa) feed trees for Gehrrl (Glossary Black-Cockatoo)
- Protect mature (parent) canopy trees, which provide important roles, habitat and resources like blossoms for Wijoon (sugar glider, squirrel glider and yellow-bellied glider)
- Protect and enhance habitat trees, as they are the home of culturally important species like Owls, possums and birds.



RESPONSIBILITY

- Ensure the right people are involved in planning and implementing fire based on their cultural connections to the land.
- Teaching young people and passing down knowledge.

RESPECT

- Being on Country, learning by observation and sharing.

RECOGNITION

- Embedding cultural connection within contemporary natural resource management practices.
- Implementing good training, strong partnerships, on ground practices and appropriate techniques.

4.2 Ecological fire

From an ecological perspective, ***Good Fire*** **is any fire that maintains the habitat and life cycles of the plants and animals found at a particular location**. This includes both the maintenance of open ecosystems where fire is needed and applied, and also the protection of adjacent fire-sensitive rainforest, where fire is actively excluded.

In the broadest sense, fire is needed in open ecosystems to:

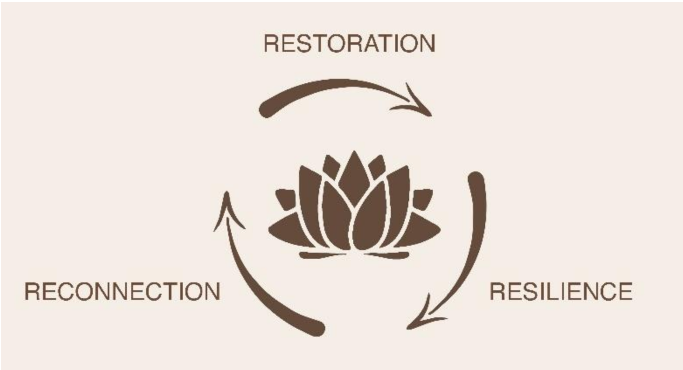
- trigger seedling germination (via heat, smoke or sunlight) and maintain open conditions for shade-intolerant plants
- maintain appropriate soil conditions (soil chemistry, soil biota) for open ecosystem plants
- maintain suitable habitat composition and structure for open ecosystem fauna
- prevent transition to closed forest

More specifically, each open ecosystem is adapted to a particular fire regime (frequency, intensity, season and extent) and *Good Fire* restoration should be guided by ecosystem-specific guidelines [11]. Among these, fire frequency is particularly important ecologically, as the interval between fires determines the composition of plant species, the structure of fauna habitat and ecosystem function. Such guidelines have been developed using a 'learning from Country' approach that examines the relationship between fire and plant life histories and/or fauna habitat. For example, the presence of plant or animal species that become locally extinct with either too frequent or too infrequent fire can indicate the tolerable fire frequency of an ecosystem (see **Section 6**).

At the time of European colonisation, open ecosystems in the Northern Rivers were finely adapted to Aboriginal and lightning fires. Now however, most open-ecosystem areas are currently in serious decline due to chronic fire-exclusion, so simply restoring historical fire frequency is a key conservation priority in many areas and likely to constitute *Good Fire* with important conservation benefits. Pre-European Aboriginal fire provides the benchmark for the restoration of *Good Fire.* However*,* much detailed knowledge of the traditional Aboriginal fire regimes in the Northern Rivers (e.g. season, extent) has been tragically lost through British colonisation and oppression of Aboriginal peoples and culture. If we are to restore *Good Fire* effectively, we will need to rebuild this lost knowledge from observing landscapes and their response to different fires through careful practice [20,21].

Ultimately, restoring Good Fire for biodiversity will involve processes of *restoration, resilience and reconnection*. The *restoration* of Good Fire is crucial to maintain the environmental conditions required by open-ecosystem plants and the habitat structures required by open-ecosystem animals.

Restoring Good Fire can improve the *resilience* of open ecosystems to global change - keeping them in optimal condition, so that they can recover from extreme disturbances. Finally, if we are to conserve our fire-dependent biodiversity, it is vital that all land managers *reconnect* with fire as a keystone ecological process and that Good Fire practices are embedded in natural resource management programs related to fire-dependent ecosystems.



RESTORATION

- restore Good Fire where it has been removed or modified
- restore environmental conditions (e.g. high light, soil chemistry & biota) to support open-ecosystem plants
- restore habitat structure (e.g. dense ground layer) to support open-ecosystem animals

RESILIENCE

- maintain open ecosystems in optimal condition so they are more resilient to climate change
- buffer the impacts of extreme fires and promote rapid recovery after extreme fires and floods

RECONNECTION

- embed Good Fire practices within contemporary natural resource management practices
- support land managers to care for Country through the restoration of Good Fire
- reconnect community to Country through education on the importance of Good Fire in open ecosystems

5 The Demise of Good Fire

At the time of British invasion (c. 1850), the extensive open forests, heathlands and grasslands of the Northern Rivers thrived in a landscape maintained by skilful Aboriginal burning and periodic lightning fires. Under this regime, many species that are now rare or threatened were likely abundant. In Byron Shire for example, the critically endangered Byron Bay Donkey Orchid was once so prolific its flowers created 'fields of yellow' on the hills around Byron Bay, while adjacent Eucalypt forests supported Greater Gliders and Eastern Grey Kangaroos [22]. Even rainforests likely benefited, with fire being used carefully around their edges to keep fuels low, thereby protecting these important, fire-sensitive resources from occasional wildfires. Today however, Aboriginal fire has been replaced by new fire regimes, leading to dramatic shifts in habitat structure and the localised decline and extinction of once-abundant plants and animals. Where fires still occur, they are typically high intensity wildfires that occur under extreme fire weather, increasing the likelihood of fires affecting fire-sensitive rainforest.

Analyses of modern fire frequency confirms an overwhelming deficit of fire across Byron Shire's open ecosystems [23], with similar patterns found across Tweed, Lismore, Ballina and Kyogle Shires. Currently, around 82-100% of dry open forest, swamp forest, heathland and grassland are overdue for fire, while around 90% of wet open forest is due for fire now (**Figure 8**). Since 2000, the area of open ecosystems burnt is only 14% of the area recommended to be burnt to maintain biodiversity, representing a landscape fire deficit of 86%.

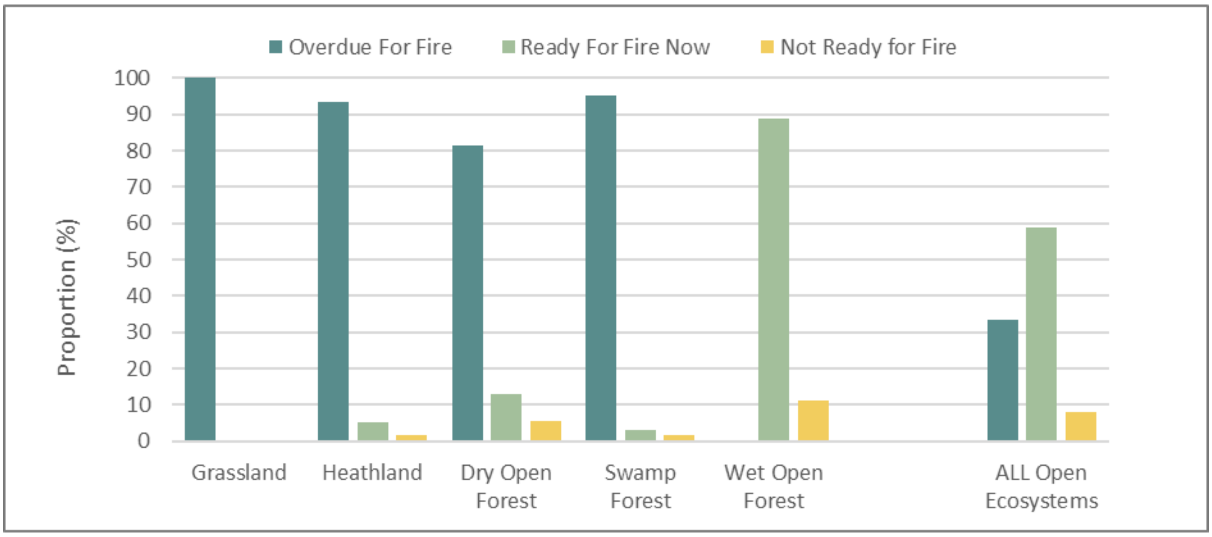


Figure 8. *Fire interval status across open ecosystem classes in Byron Shire in 2022.*

5.1 Cultural consequences of fire exclusion

5.1.1 Overview

Exclusion of fire on country that needs it, is excluding Fire Country.

It is like not calling it/them by name and taking away its/their identity. If we belong to that Country and we know the Cultural Fire for that Country, then when it's not there, it must be the stories are not there either. These stories have been with that place since fire taught lore to our ancestors. Why are we not there burning anymore? Lightning can bring fire or rain to Country, and we can change Country like lightning as we have learnt ways to share and practice.

The descendants might be there. Maybe they're still there somewhere else in the landscape. But regardless of where the people, plants, animals and the fires are, it comes from the Fire Country that needs to burn a good way. We know that the people are not there, but it's not just the people. Also, some of them are plants, animals, the features of the landscape, the structure, the kinship, its identity, you know, healthy functional stages of growth, and abundant change. It's not just fire. There are many other entities, but the question is the consequences of excluding fire and it only matters if Fire Country people let it burn because it is Good for Country. Well, maybe not. The way Country's been changed, as well. Colonisation, land changes and suppression have done a lot of damage to Country, and it needs help to heal. The lightning fire doesn't always get to run anymore, so it needs to be respected as it likes to run when it gets the chance, that's the culture of lightning. It's not easy learning fire from lightning. Much better to move through the landscape with Cultural fire before the fire (lightning) storms come. Understanding that good way for Country and how people learnt their stories is the best way to learn. They all will learn from the lightning in the end, which can start before or after the rain. They learnt from the change, Good Fire comes from knowing where fire belongs and does not. Excluding fire from rain country, comes by burning away from the rain country or too it's edge, skin layer. Reading Country is reading the skin of the land. People learnt to make fire for different reasons and for different skin. We all know about campfires for cooking and light. Burning the good way is the same for the plants and animals, good fire brings food and energy to create new and old life. Fires can get away, which makes people scared to light them. People have been chasing fire as long as fire has been chasing them. When we exclude that fire, we lose that story, people forget to follow and make fire. And we end up where we are here today reading a plan that the Country can teach us in every way. What are we talking about? Fire people that have no country or country that has no Good Fire.

When we exclude Good Fire in these landscapes we see entities move around in different ways. Some in a good way and others a bit cheeky. They start to come in and others can lose their way because they don't really know their way around that country. Others have learnt the lore there and now have common sense and purpose. They have shared stories and are learning in a collective response.

The cultural consequences of fire exclusion are a deterioration in cultural landscapes and resources, creating a lack of cultural places and pathways for community to connect and care for Country.

Bringing Good Fire back to fire country is a way that country and people can heal and rebuild kinship.

5.1.2 Specific Consequences

Cultural consequences of fire exclusion can be grouped into three key areas. Including:

1. Loss of fire-dependent cultural values that are maintained by regular fire
2. Loss of fire-sensitive cultural values that are at increased risk from severe wildfire
3. Inability to practise cultural fire and cultural obligations to care for Country

5.1.3 Loss of fire-dependent cultural values that are maintained by regular fire

There are many cultural values that were historically maintained by regular fire and will decline if fire is excluded from an area. Open cultural landscapes (e.g. grassy forest), grassy pathways that connect important sites and important open sites used for gathering and ceremony can quickly become overgrown if they are not maintained by regular fire. Traditional plant resources, such as bushtucker and medicine plants can also be lost from the land when dense shrubs and saplings grow too thick and steal the light from grasses, tubers and ferns in the understorey. Fire exclusion also causes the decline of native fauna which normally depend on the flush of new growth and other resources that peak in the first few years after fire.

5.1.4 Loss of fire-sensitive cultural values at increased risk from severe wildfires

Many cultural values can be damaged or destroyed by severe wildfire. Traditionally, these values were protected from wildfire using cool burns to reduce fuels in and around important sites. However, with the loss of Good Fire, fuel build-up in and around these values makes them vulnerable to destructive wildfire.

Cultural values that can be damaged or destroyed by hot fires, include:

- culturally modified trees (scars or engravings)
- fire-sensitive rainforest and associated culturally significant species
- culturally important food and medicine plants that are intolerant of hot fires
- culturally significant animals
- rock-face art and artefacts that can be destroyed by cracking

5.1.5 Inability to practise cultural fire and cultural obligations to care for Country

The disruption of traditional fire practices since British invasion has removed the ability for Aboriginal people to care for Country. Caring for Country is a fundamental cultural obligation among Indigenous Australians and an important way for people to maintain their connection to Country. The use of Good Fire means healing Country and when you heal Country, you heal people.

5.2 Ecological consequences of fire exclusion

Fire exclusion (low frequency fire) is linked to a wide range of negative ecological consequences in Australia and globally. Many ecological consequences relate to structural changes that occur with time since fire (e.g. canopy closure from increased woody plant cover), while others are not dependent on structural change, but relate to other processes including changing soil chemistry (e.g. increasing soil acidity or soil nitrogen) or a lack of fire-related cues for reproduction (e.g. heat, smoke).

Across open-ecosystems generally, fire exclusion 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. Dieback of canopy dominants & open forest displacement
5. Establishment of transformer weeds
6. Increased risk of high intensity bush fire

5.2.1 Structural change and ecosystem displacement

Structural change and displacement of fire-dependent vegetation communities due to fire exclusion is a global phenomenon, well documented in Australia, North America, South America, Africa and India [7,10,24–27].

Open forests are characterised by an 'open' tree canopy above a ground-layer plant community of shade-intolerant graminoids, herbs and shrubs [28,29]. These ground-layer plant communities: contain the majority of open forest 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 [29,30]. In these communities, regular fire promotes high ground-layer density and richness, by preventing competitive exclusion of grasses, herbs and shrubs by taller woody plants [31,32]. Without fire however, tree cover progressively increases, reducing light, water and nutrient availability for understorey plant species [33,34]. Canopy closure and groundlayer declines in open forest can result from increased densities of sclerophyll trees (e.g. wattles, she oaks, eucalypts, paperbarks) [35–37], or from fire-sensitive rainforest pioneers expanding from nearby rainforest areas [32,38] (i.e. rainforest invasion).

5.2.1.1 Canopy closure by sclerophyll trees

Canopy closure by sclerophyll trees has been widely reported in Australia, including for species of Allocasuarina [35,39,40], Acacia [37,41], Leptospermum [42,43], Melaleuca[44] and Eucalypts [45]. Sclerophyll trees may cause canopy closure by invading treeless ecosystems (e.g. grassland, heathland) or by increasing their abundance and crown cover within open forests in which they are indigenous, also referred to as 'woody thickening'. In both cases, a major consequence is elimination of ground layer plant communities through shading (**Figure 9**).

Figure 9. *Typical clay heathland (left) and clay heathland invaded by sclerophyll trees (right) showing loss of the heathy ground layer community beneath the tree canopy. Byron Bay.*

Although the extent of canopy closure by sclerophyll trees in the Northern Rivers has not been assessed, local assessments indicate that is a significant issue in coastal heathlands and Paperbark forests in the region. For example, around two thirds of the endangered Byron Graminoid Clay Heath has been displaced by invading sclerophyll trees since the 1960s [46]. Similar declines have been observed in wet heathland south of Suffolk Park [47] (**Figure 10**) and west of Brunswick Heads.

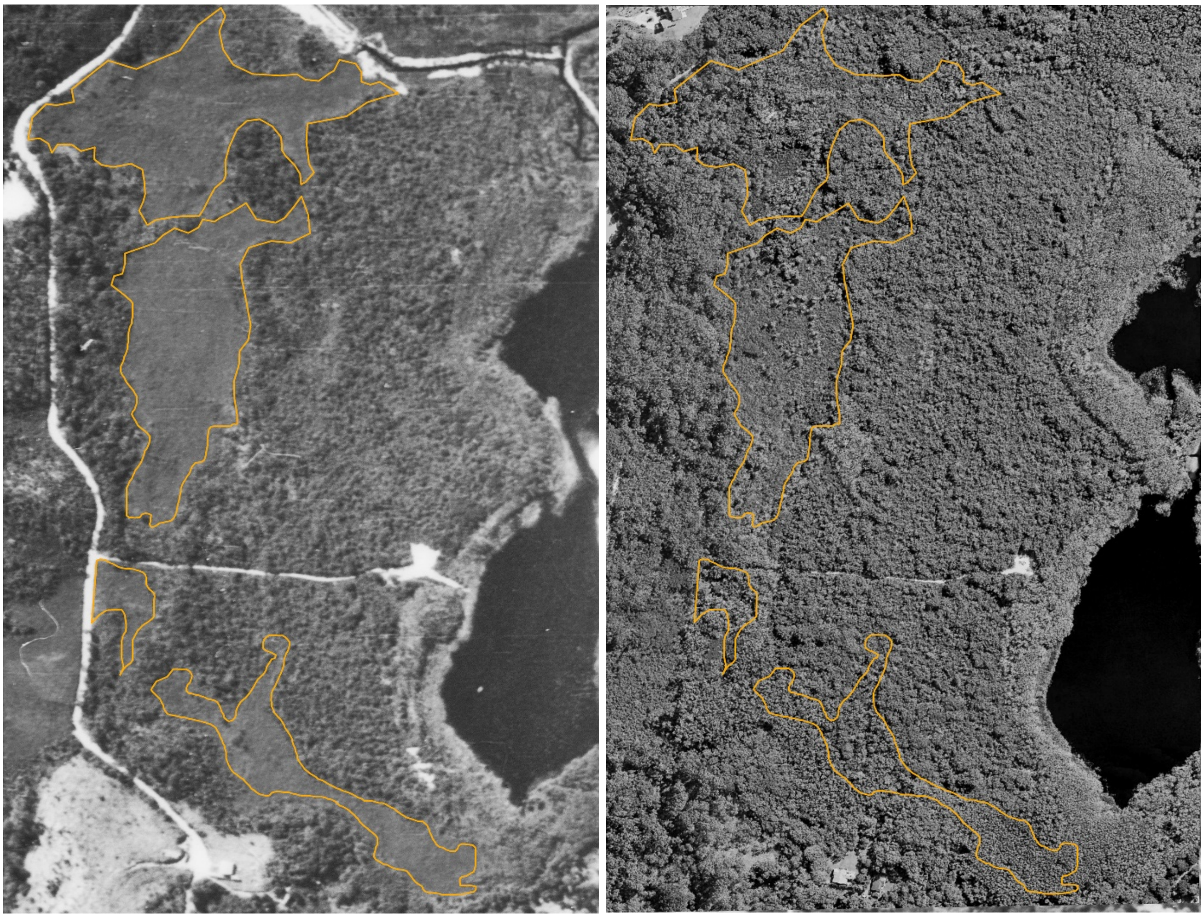


Figure 10. *Sclerophyll tree encroachment and displacement of wet heathland south of Suffolk Park between 1971 (left) and 2015 (right). Note that the northern and southern sections have transitioned completely from heathland to forest, while the central section is still in the early stages of transition with only scattered trees.*

5.2.1.2 Rainforest invasion

The invasion of rainforest pioneers into fire-excluded open forests is a global phenomenon [7,26,48–50], and has been widely reported along the coast and ranges of NSW and SE QLD [10,51–57]. The potential for rainforest invasion of open forests is particularly high in regions of high rainfall [49,58], low fire frequency and a moderate to high proportion of rainforest seed-source areas.

A general model of rainforest invasion 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 [32,54] (**Figure 11**). The ecological consequences of rainforest-invasion are outlined in the following sections and summarised in **Appendix A**.

Figure 11. *Comparison of typical and rainforest-invaded swamp sclerophyll forest: a) recently burnt (8 years since fire), and b) long-unburnt (>50 years since fire) and rainforest-invaded.*

Rainforest invasion in fire-excluded open forests may also be accelerated by global climate change through increased rainfall [59], increased atmospheric humidity [60], improved forest water-use efficiency [61], CO_2 -fertilisation causing increased growth rates [62,63] and enhanced resilience to browsing[64].

After 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 [65]. Premature dieback of canopy trees is further outlined in **Section 5.2.4**.

POTENTIAL FOR RAINFOREST INVASION & TRANSITION IN THE NORTHERN RIVERS

The potential for change in the region is indicated by recent vegetation mapping across Byron Shire, where since the 1990s, 35% of wet sclerophyll forest has transitioned to rainforest in the absence of fire [47] (**Figure 12**). A further 75% of dry sclerophyll forest was reclassified to wet sclerophyll forest in that time, presumably due to the increasing prominence of rainforest pioneers in the understorey. The Shire’s high rainfall and widespread distribution of suitable soils and rainforest seed-source areas further suggests a high potential for rainforest transition throughout the fire-excluded open-forest of the area.

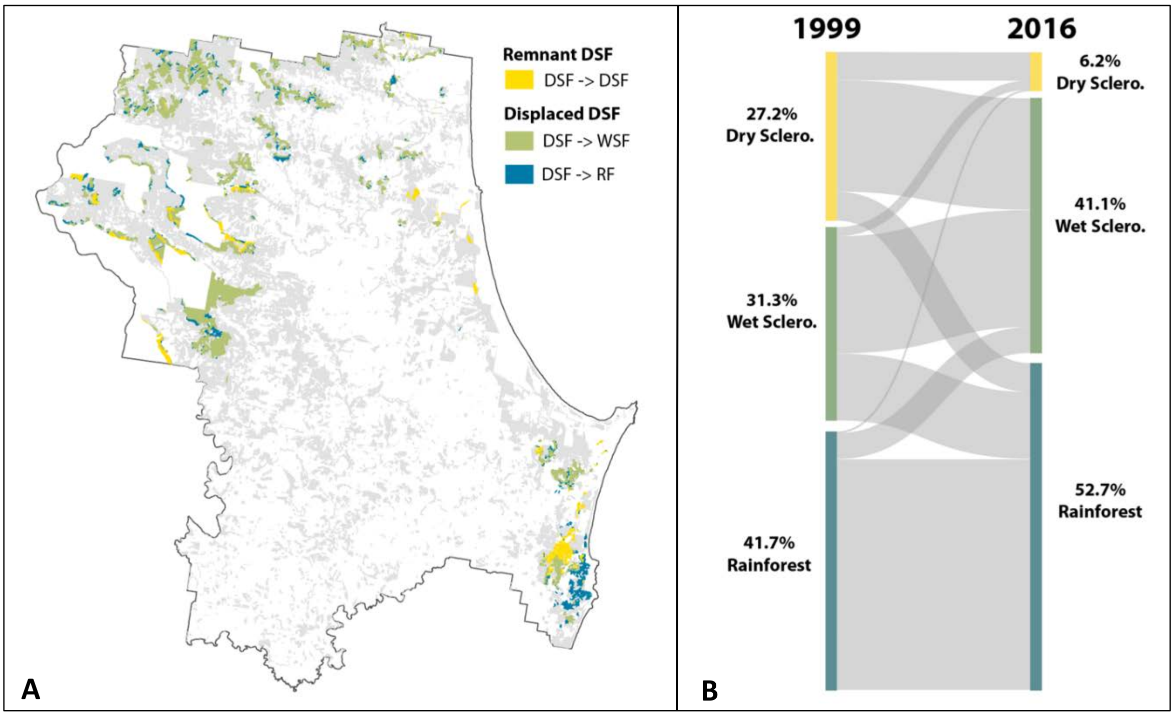


Figure 12. *Indicative extent of rainforest invasion in Byron Shire between 1999 and 2016, including: (A) the reclassification of dry sclerophyll forest to more-rainforest associated forest types; and (B) the redistribution and changing total extent of different forest types. DSF – dry sclerophyll forest; WSF – wet sclerophyll forest; RF – rainforest; Sclero. – sclerophyll forest.* [66].

5.2.2 Localised decline and extinction of open-forest flora species

Several mechanisms of open-ecosystem flora decline, and localised extinction have been linked to fire-exclusion, including:

- Premature death of shade-intolerant understorey flora through shading [42,56,67]
- Failed reproduction and recruitment of flora requiring fire or bare-earth seed beds for germination [68–70].

Most of the floristic diversity of open forests typically occurs in the ground layer and is shade intolerant, making it vulnerable to displacement by a dense midstorey of rainforest pioneers, overabundant sclerophyll trees or transformer weeds. For example, a recent study in fire-excluded dry sclerophyll forest in the region [56], found that rainforest pioneers had eliminated over half of the understorey plant species, and reduced ground cover and density of dry forest specialists by ~90% (**Figure 13**). 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.

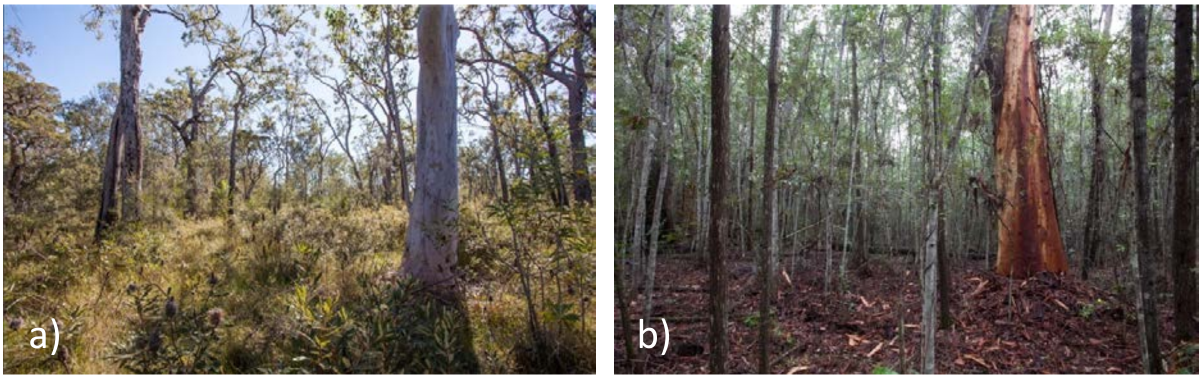


Figure 13. *Displacement of understorey plant community in dry sclerophyll forest in Bundjalung National Park, showing a) regularly burnt forest (4 years since fire), and b) fire-excluded rainforest-invaded open forest 16 years after fire.*

While flora species with persistent soil seed banks may remain on the site until the return of fire, taxa with transient or canopy-stored seedbanks (e.g. members of the families Xanthorrhoeaceae, Proteaceae and Myrtaceae) become locally extinct with the death of the standing plant population [67,71]. A study of seed-bank longevity in open 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 does not return during this period [72]. Finally, the loss of the dense ground layer can remove the ability for fire managers to implement regular fires under moist, mild conditions, severely undermining the capacity for restoring appropriate fires[73].

5.2.3 Localised decline and extinction of open-forest fauna species

In Australia, **fire-exclusion** has been linked to the declining habitat suitability and displacement of mammals [74,75], birds [57,76] and reptiles [77].via a range of mechanisms, including:

- Loss of ground cover foraging, breeding and or sheltering resources as ground layer vegetation is lost to canopy shading [74,78,79]
- Impeded movement under canopy through midstorey thickening [80,81]
- Reduced hollow formation from fire scarring of canopy trees [82,83]
- Accelerated decay of woody debris in humid conditions under closed canopy [84]
- Reduced ectotherm/homeotherm heating opportunities below closed canopy [77]
- Increased abundance of feral predators in long-unburnt vegetation with reduced ground layer vegetation [85]
- Reduced age class diversity and structural formation diversity [86,87]
- Reduced habitat connectivity [88]

More specifically, **rainforest invasion** into Australian open forest has been shown to affect the habitat suitability and species diversity of mammals [74,75,81,89], birds [32,76] and invertebrates [90,91]. For example, a recent study of insectivorous bats in fire-excluded Eucalypt forest in the region [81] 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 midstorey. 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.

5.2.4 Dieback of canopy dominants & open forest displacement

Fire exclusion and invading rainforest pioneers have been shown to accelerate the decline of open forest canopy trees through:

- suppressed reproduction and recruitment of canopy trees beneath the dense midstorey [68,69,92]
- increased competition for soil water availability during droughts [93,94]
- alteration of ectomycorrhizal communities mediated by soil chemistry [95,96]
- facilitating Bell Miner Associated Dieback (BMAD) by providing critical nesting conditions for bell miners [97–99].
- locking up phosphorous and/or cations in rainforest litter and midstorey biomass [33]

Most open forest canopy trees (e.g. *Eucalyptus, Corymbia, Lophostemon, Melaleuca*) are dependent on fire for recruitment and without future fires, existing adult trees may become the last of their kind on the site. The reproduction and recruitment of most open forest trees is cued to coincide with the reduced competition and increased availability of resources within gaps of the post-fire environment [100]. Successful seedling establishment of open forest trees requires periodic understorey removal by fire and subsequent sun exposure of the bared soil in large gaps [68,69] and also reduction of seedling pathogens and consumers [92].

Long-term fire exclusion can also have profound negative impacts on the health of existing trees, through changes in open forest soils, including altered pH, Nitrogen and water availability and alteration of mycorrhizal and other microbial communities [33,94,96]. The development of a rainforest midstorey following fire-exclusion can further exacerbate these changes, and has been attributed to crown decline and premature mortality of dominant overstorey Eucalyptus trees [85,92]. Rainforest development typically modifies the soil physical and chemical environment to favour invading rainforest trees at the expense of open forest canopy trees. The mechanisms accelerating crown decline include increased competition for soil water availability during droughts [32,84] and locking up essential Phosphorous and/or cations in rainforest litter and midstorey biomass [33].

Bell Miners (*Manorina melanophrys*) require dense midstorey cover (c.2-6m in height) to nest and establish colonies [98,101] and readily nest in many native understorey species as well as the introduced Lantana [102]. Thus, long-unburnt open forest with a dense midstorey of sclerophyll or rainforest trees provides ideal nesting habitat for Bell Miners [98,99]. Once established, Bell Miner colonies encourage over-abundant psyllid populations, which can lead to Bell Miner Associated Dieback (BMAD) of open forest trees. BMAD is listed as a Key Threatening Process under the NSW *Biodiversity Conservation* Act and has caused the decline of tens of thousands of hectares of Eucalypt forest from south east Queensland to Victoria [99]. BMAD is widespread in the western half of Kyogle and Richmond Valley Shires. However, the recent establishment of Bell Miner colonies in coastal Tweed and Byron Shire (e.g. Uki, Yelgun, Mullumbimby), signals a high potential for BMAD as an emerging threat to the region's open forests along the coast.

With sufficient time without fire and advanced canopy dieback, rainforests may completely displace open forest [65], as remnant open forest canopy trees senesce with age or decline prematurely in the unfavourable environment created by the developing rainforest subcanopy (**Figure 14**).

Figure 14. *An area of swamp sclerophyll forest in Ewingsdale that has been fire-excluded for at least 70 years. Only old-growth Paperbarks remain on site a) with seedlings unable to recruit in the deep shade and deep litter. The Paperbark canopy b) is progressively being replaced by rainforest trees such as Bangalow Palms and Strangler Figs.*

5.2.5 Establishment of transformer weeds

Transformer weeds are invasive plants which can undermine the ecological processes that maintain the health of native ecosystems and the habitat of associated plants and animals. Numerous weed species are fire-sensitive, and like fire-sensitive rainforest trees, their establishment is favoured by fire-exclusion (e.g. Camphor Laurel, Privets, Umbrella Tree, Broad-leaved Pepper). Like rainforest pioneers, these weeds have the potential to form a dense midstorey or canopy (**Figure 15**) and can therefore have the same impacts in open forests, such as displacement of flora & fauna. 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:

- displace open forest understorey plant communities and canopy trees through competition
- degrade or eliminate open forest fauna habitat
- disrupt the fire regime of open forests through alteration of fuel arrays and microclimatic conditions [103–105].

Although most transformer weeds are killed by fire at the seedling and small sapling stage, like rainforest pioneers, larger individuals of some species (e.g. Camphor Laurel) usually resprout after fire, allowing them to remain in the ecosystem. Despite this, frequent fire still plays an important role in reducing habitat modification by these transformer weeds, including:

- preventing individuals forming a dense midstorey and shading out the shade-intolerant understorey
- reducing seed production by keeping individuals in a secondary-juvenile stage
- reducing seed immigration, by suppressing local fruit production and the subsequent attraction of frugivorous birds carrying weed seed from offsite.

Figure 15. *Dense subcanopy of the transformer weed Camphor Laurel in coastal koala habitat in Ballina LGA. These Camphor Laurels are likely to replace the koala feed trees on this site without future fire, while the shade beneath the dense subcanopy is already transforming the community though suppression of groundlayer vegetation and subsequent decline in floristic diversity, fauna habitat and ecosystem flammability.*

5.2.6 Increased risk of high intensity bush fire

5.2.6.1 Fuel accumulation & increased high intensity bush fires

Australian open forests are among the most fire-prone ecosystems on earth [106] and under conditions of severe fire weather and high fuel accumulation, resulting crown fires are typically beyond human fire suppression capabilities (**Figure 16**). 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 and saplings). Fuel accumulation is often most rapid in the decade after fire, although fuels in all layers can continue to increase for several decades [107]. While recent research indicates that flammability can later decline in some forest after extended periods without fire [108,109], this likely comes at the expense of open-forest biodiversity and ecological function[108]. Where fire exclusion leads to increased forest flammability, it maximises the threat of catastrophic wildfire both impacting fire-sensitive conservation values and endangering lives and property.

Figure 16. *High intensity wildfire in open Eucalypt forest in coastal NSW. Dan Himbrechts/EPA.*

5.2.6.2 Biodiversity values vulnerable to high intensity wildfire

FIRE-SENSITIVE RAINFOREST

Fires that spread through open forest usually self-extinguish upon reaching the rainforest boundary, where fuels are usually too damp to burn. However, particularly hot and dry bushfire seasons can cause rainforest fuels to dry out, allowing fires to penetrate rainforest margins and damage their fire-sensitive conservation values. The impact of fires on rainforest increases with fire intensity, with high intensity fires capable of deeper penetration and more severe and extensive scorching of the rainforest canopy. The risk of high intensity rainforest fires is increased where adjoining open forest has accumulated high fuel loads, making the wildfire more difficult to control and increasing its capacity to preheat and dry fuels along the rainforest margin ahead of the fire front.

Although most rainforest plant species can survive and recover from wildfire through resprouting [110,111], crown scorching temporarily forces open the rainforest canopy, profoundly changing the habitat structure until the canopy can close over again following years of recovery. Prior to canopy recovery, likely impacts of fire penetration on threatened fauna include:

- temporary loss of foraging resources (e.g. rainforest tree fruit for rainforest pigeons)
- temporary loss of dense roosting habitat for rainforest pigeons, the Eastern Tube Nose Bat and the Queensland Blossom Bat
- temporary loss of rainforest litter for Mitchell's Rainforest Snail

OPEN FOREST VALUES

Although open forests are generally adapted to fire, high intensity wildfires can have much more severe impacts on open forest fauna than low intensity surface fires, including:

- increased death of less mobile canopy fauna such as koalas
- temporary reduction of foraging resources for fauna dependent on open forest tree nectar, foliage, seeds or insects
- increased loss of tree hollows and large fallen logs
- more extensive loss of refuge areas and habitat resources across the landscape

The impact of crown fires has been relatively well documented for koalas, and similar impacts are likely for other fauna that utilise the open forest trees. High-intensity canopy fires pose a serious threat to koalas, particularly in areas of fragmented habitat. High intensity canopy fires can cause death or injury of koalas [112]. Koalas which survive the initial canopy fire may still succumb to starvation following widespread canopy scorch [113], or dog attack and road mortality as animals move in search of unburnt habitat [114].

Resource depletion from intense bush fires is short-term for koalas, and individuals surviving in unburnt refuge areas, may recolonise burnt habitat and utilise resprouting trees within months of the fire for both food and shelter [114]. However, in fragmented habitat, high-intensity bush fires have the potential to eliminate koalas from isolated patches of koala habitat, and if the fragmentation limits koala movement across the landscape, repopulation of previously burnt areas after habitat recovery may be restricted or impossible.

SWAMP FOREST (INCREASED RISK OF PEAT FIRES)

Swamp forests subject to seasonal inundation often accumulate peat (partially decayed, densely packed organic matter) in their soils. During extended dry periods, lowered water tables allow the peat to dry and become vulnerable to ignition. Once ignited, peat fires can burn below the ground surface and in severe cases, extensive soil subsidence and / or burning of tree roots can cause widespread tree collapse (**Figure 17**). Although this Plan recommends that all planned burns avoid the ignition of peat soils, fires in peatlands do occur naturally and are likely to be important drivers of habitat heterogeneity by creating areas of open water or openings in the canopy in otherwise uniform expanses of peat swamp.

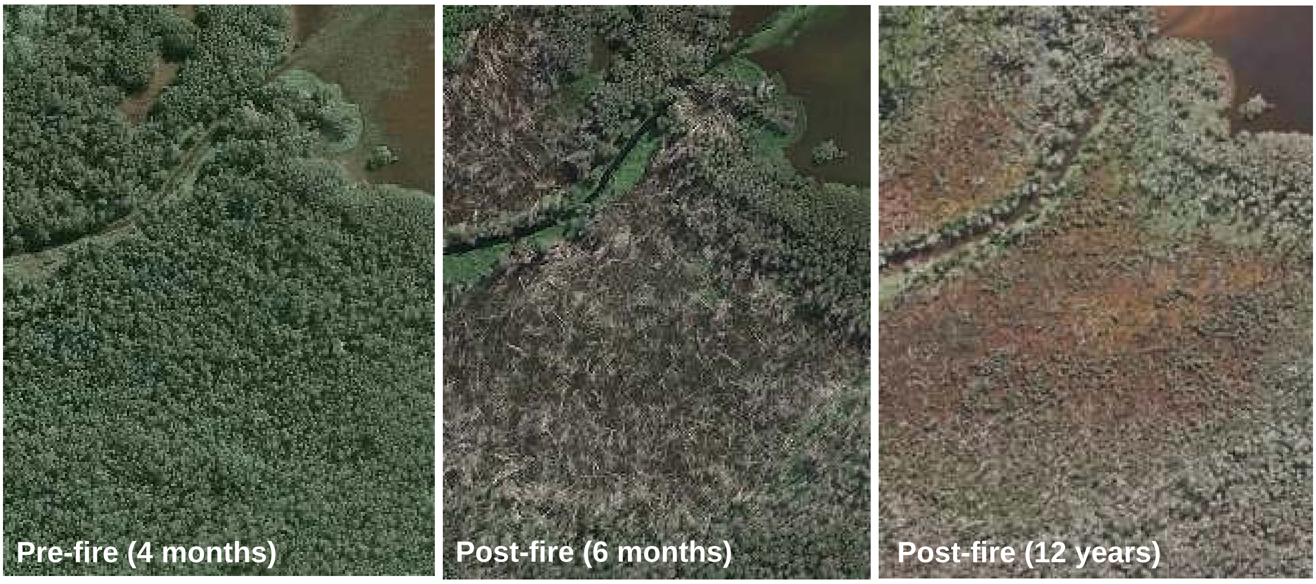


Figure 17. *Widespread collapse of Paperbark forest caused by peat fire in December 2009 on the western shore of Cudgen Lake* [115].

5.2.7 Lower resilience to wildfire impacts

An emerging issue is that wildfire impacts are often more severe in previously long-unburnt sclerophyll forests compared to those that were previously subject to frequent fire[116] (Figure 18), including:

- higher mortality of canopy trees, and
- overabundant postfire regrowth of wattles and rainforest pioneers.

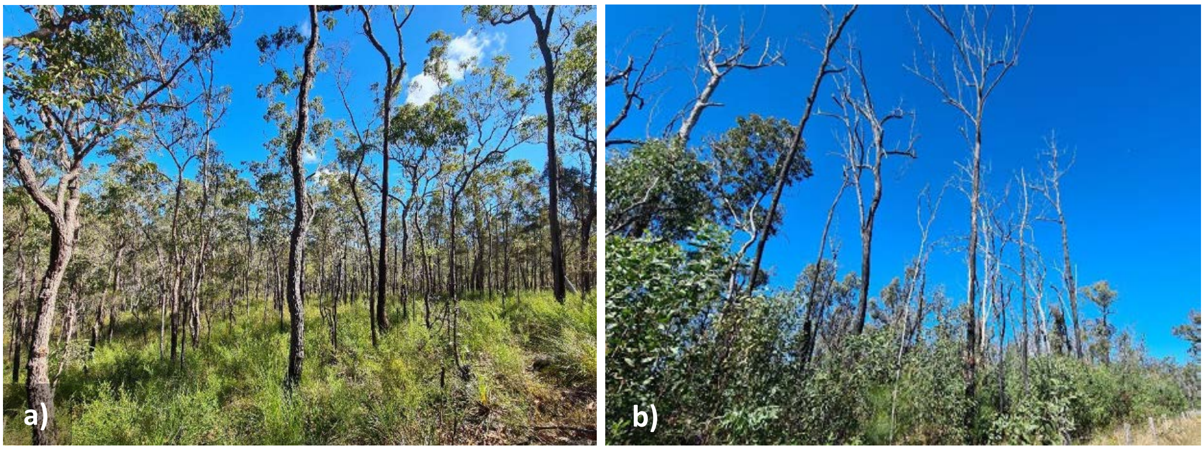


Figure 18. *Comparison of wildfire effects on forests with different fire frequencies prior to the wildfire, including a) frequent fire (c. every 2-5 years) and long-term fire exclusion (c. 25 years). Note the difference in canopy tree health, midstorey density and ground layer density between these forests. Photos: Max Watt.*

5.2.7.1 Higher mortality of canopy trees on previously long-unburnt sites

While the mechanisms have not been well studied, increased canopy mortality is likely due to high intensity crown fires on long-unburnt sites fuelled by dense tree and shrub ladder fuels in the understorey. While on frequently burnt sites, midstorey fuels are likely lower, resulting in lower intensity wildfires (surface fires) with fewer effects on canopy trees[116]. Increased competition from higher density of midstorey trees, both before and after the fire, may be another factor increasing canopy mortality on previously long-unburnt sites.

5.2.7.2 Overabundant sapling regrowth on previously long-unburnt sites

Another wildfire impact to previously long-unburnt sclerophyll forests is the overabundant post-fire regrowth of saplings comprising wattles, rainforest pioneers and Eucalypts. In these forests, long fire-free periods likely allows accumulation of propagules[116], including bird-dispersed wattles and rainforest pioneers. With subsequent, high-intensity fires then promoting abundant recruitment of wattles and rainforest trees [110,117].

Excessive sapling density smothers shade-intolerant grasses, shrubs and herbs of subtropical eucalypt forest [56,117], and it is these plants that provide most of the species diversity in these forests and provide key habitats for many open forest fauna. The loss of the dense ground layer can remove the ability for fire managers to implement regular fires under moist, mild conditions, severely undermining the capacity for restoring Good Fire [73]. Conversely, overabundant saplings can cause a positive flammability feedback, whereby intense fire triggers dense sapling recruitment, which then grow rapidly to increase elevated fuel loads and subsequent fire intensity [118]. Thus, providing a mechanism for high-severity fire to promote further high-severity fire [119].

5.3 Endangered Ecological Communities in the Northern Rivers threatened by low frequency fire

Low frequency fire has been specifically identified as the primary threat from altered fire regimes for a number of fire-dependent endangered ecological communities that occur in the Northern Rivers (**Table 1**).

Table 1. *Fire-dependent Endangered Ecological Communities of the Northern Rivers Region with identified threats associated with low frequency fire as defined in the community profile* [120].

Endangered Ecological Community	Threats Associated with Low Frequency Fire (DPE 2021)
Byron Graminoid Clay Heath	Low frequency fire can cause canopy closure, which shades out ground layer flora communities and fauna habitat.
Coastal Cypress Pine Forest	Low frequency fire can cause canopy closure, which shades out ground layer flora communities, displaces fauna habitat and prevents gap creation required for regeneration of the dominant species
Grey Box—Grey Gum Wet Sclerophyll Forest	Low frequency fire can cause canopy closure, which shades out ground layer flora communities, displaces fauna habitat and encourages Bell Miner.
Subtropical Coastal Floodplain Forest	Low frequency fire can cause canopy closure, which shades out ground layer flora communities, displaces fauna habitat and encourages Bell Miner.
Swamp Oak Floodplain Forest	Low frequency fire can cause canopy closure, which shades out ground layer flora communities and fauna habitat.
Swamp Sclerophyll Forest on Coastal Floodplains	Low frequency fire can cause canopy closure, which shades out ground layer flora communities and fauna habitat.

6 Good Fire Protocols

A *protocol* is defined here as a set of procedures and guidelines for undertaking an activity.

6.1 Cultural protocols

A range of Aboriginal cultural protocols relate to cultural burning and should be followed when preparing and implementing Good Fire Restoration Plans. Such protocols can be broadly summarised into four key areas, as outline below. Traditional knowledge holders should be consulted to identify any additional cultural protocols relevant the property.

Respect for Country: Cultural burning is conducted with a deep respect for Country and natural cycles. This involves considering the seasons, weather patterns, kinship relationships and other environmental factors to ensure that Country is treated in a way that is respectful and sustainable.

Knowledge sharing: Two levels of knowledge are recognised in Aboriginal cultural lore [121]. *Sacred knowledge* includes knowledge only shared between appropriate knowledge holders, and includes special language, stories, medicines and spiritual beliefs. Alternatively, the use of fire to care for Country is *shared knowledge*, which all custodians of Country (indigenous and non-indigenous) are obliged to i) learn and share with each other and ii) to help others rebuild their own knowledge on their own country and tailor this for their own place [121]. Importantly, when preparing Good Fire plans, traditional knowledge holders should be consulted on specific cultural and kinship relationships and cultural indicators held within Country and the Plan should acknowledge the knowledge source and traditional elders.

Permission and consultation: Before preparing and implementing Good Fire Restoration Plans, it is important to seek permission from the traditional custodians of the land and consult with them on the appropriate methods and timing for burning. This ensures that cultural protocols are respected and that the practice is carried out in a way that is culturally appropriate and sensitive. If the Aboriginal knowledge holder preparing the cultural components of the Plan doesn't have suitable authority to fulfil this protocol, they should consult with appropriate knowledge holders and elders for that location.

Monitoring and evaluation: Aboriginal protocols around cultural burning also involve ongoing monitoring and evaluation of the practice to ensure that it is achieving its intended outcomes and is not causing harm to the land or people. This helps to ensure that cultural burning remains a sustainable and effective practice for managing the land.

6.2 Ecological protocols

From an ecological restoration perspective, *Good Fire* protocols broadly include policy and legislation relating to biodiversity conservation and ecological restoration. This section broadly outlines key guidelines and procedures that relate to the ecological restoration of *Good Fire* in the Northern Rivers region, including:

1. Recommended fire regimes
2. Ecological restoration guidelines
3. Ecological aims and rationale
4. Policy support for restoring Good Fire in the Northern Rivers region

6.2.1 Recommended fire regimes

Good Fire Restoration Plans will adopt the recommended fire regimes of the **Planned Burn Guidelines: Southeast Queensland Bioregion (SEQ Guidelines)** [11]. The SEQ Guidelines provide detailed fire regime recommendations for all major vegetation classes in the northern Rivers region (**Table 2**), including recommendations to address specific fire and biodiversity issues common to the region.

Table 2. *Recommended fire intervals for different vegetation classes in the Northern Rivers region* [11].

Vegetation Classes	Recommended Fire Interval (years)
Heathlands	
coastal	6 - 12
montane	20 - 50
Dry Sclerophyll Forest	
grassy	1 - 6
shrubby	4 - 10
Swamp Sclerophyll Forest	
grass / shrub	6 – 20
heathy shrub	8 – 12
sedge / fern	12 -20
Wet Sclerophyll Forest	
grassy	3 – 5
fern / shrub	8 – 20
rainforest understorey	20 – 100
Rainforest, Saline Wetlands	No Fire

Applying recommended fire intervals to a property may be limited by the accuracy of the available vegetation mapping. To accurately determine vegetation and recommended fire frequency for individual properties, vegetation types must be verified by expert, on-ground site assessment to determine the structural formation of each stand. A key for identifying forest formations in the Northern Rivers is provided in **Appendix C**.

Although the Northern Rivers is also covered by the *NSW Guidelines for Ecologically Sustainable Fire Management* [122], use of the SEQ Guidelines is preferred for Good Fire restoration for several reasons. Firstly, the Northern Rivers is located within the Southeast Queensland Bioregion, which extends south to Coffs Harbour [123]. Secondly, the use of regionally specific guidelines is consistent with the provisions of the following guidelines and strategies:

1. *NPWS Fire Management Manual 2021-2022* [124], which states that:

   a) '*where more specific evidence-based biodiversity thresholds have been developed for a particular geographical area,* using local floristic and fire response information… *these should be used instead*'.

2. *Northern Rivers Regional Biodiversity Management Plan (Action 4.2.2)* [125]:

   a) Investigate options for utilising the regional fire thresholds recommended by the Nature Conservation Council Hotspots Fire Project and the Southeast Queensland Fire and Biodiversity Consortium [QPWS 2022]

   b) Recommendations should be used by regional bushfire management committees, DECCW [DPE] and Forests NSW.

3. *Bush Fire Risk Management Planning Guidelines for Bush Fire Management Committees* [126].

Finally, the *SEQ Guidelines* have three key advantages over the NSW Guidelines, including that they:

1. specifically consider the structural change and competitive exclusion with time since fire.

2. are specific to this region, where the warm and wet subtropical climate accelerates postfire plant growth, which in turn leads to faster: attainment of plant juvenile periods; competitive exclusion of ground layer plants by taller plants; faunal habitat change; and transition to closed forests.

3. *incorporate a more practical approach based on site assessment of structural condition, consistent with traditional Aboriginal methods.*

Note: if seeking approval for a burn under the *Bush Fire Environmental Assessment Code* [127], it may be required to consult the recommended intervals within the *NSW Guidelines for Ecologically Sustainable Fire Management* [122].

6.2.2 Ecological restoration principles

The restoration of historical fire regimes is embedded in the *National Standards for the Practice of Ecological Restoration in Australia* [128], which identifies key principles underpinning ecological restoration, and outlines the steps required to plan, implement, monitor and evaluate a restoration project to increase the likelihood of its success. In relation to Good Fire, the Standards recognise the following

- Indigenous fire management regimes are intrinsic to the structure and function of some local native ecosystems
- historical fire regimes (disturbance regimes) are a key component of ecosystem function, which in turn is key ecosystem attribute that must be restored to achieve a high level of recovery.
- applying appropriate fire regimes as an ongoing activity constitutes *ecological maintenance* where it is necessary to sustain the attributes of an ecosystem.

Additionally, the key restoration principles of the standards state:

- that restoration should be based on an appropriate reference ecosystem with historical structure, composition and function (e.g. fire regime), and
- that these reference ecosystem attributes should provide the basis for restoration targets on the restoration site.

The general reference *structure* and *function* of open ecosystems (fire country) is illustrated in Figure 4 and typically includes an open canopy, a dense ground layer and regular fire. More specifically, old-growth open-forests (dry, wet and swamp) in localities with appropriate fire regimes, are characterised by:

- an open canopy (<70% cover)
- a dense ground layer (>30%) of graminoids, heathy shrubs and/or ferns
- relatively frequent fire consistent with the SEQ Guidelines

Importantly, locating suitable open-forest reference sites in many areas of the Northern Rivers is severely limited wherever there has been a general deficit of landscape fire over the last 50 years, including most of Tweed, Byron, Ballina and Lismore Shires. Suitable open-forest reference sites need to be located where historical fire regimes still create a range of successional states (e.g. Richmond River, Clarence and parts of the Tweed Local Government Areas). Examples of reference open-forests are shown in **Appendix F**.

6.2.3 Ecological aim and rationale

The overarching aim for restoring Good Fire is the **reinstatement of historical fire regimes through planned burns, to maintain open forest health and function and reduce the risk of catastrophic bushfires to fire-sensitive biodiversity.**

6.2.3.1 Rationale for restoring historical fire regimes for biodiversity

Fire is a keystone ecological process in open forests, and planned burns are crucial for restoring and maintaining open forest health. A key objective of restoring regular fire to open forests to **reduce overabundant midstorey saplings** (rainforest, sclerophyll, transformer weeds), which in turn is expected to:

- restore ground layer vegetation (and associated fauna habitat) through the restoration of sunlight to ground level
- restore the openness of below-canopy foraging habitat for insectivorous bats, owls, raptors and gliders
- restore basking opportunities for ground dwelling reptiles and frogs
- maintain the health of canopy trees (and associated fauna habitat) by reducing root competition for water and nutrients
- improve canopy tree seedling recruitment through the restoration of sunlight to ground level
- increase fallen log habitat through reduced rates of decay
- reduce abundance of feral predators (cats, foxes) which favour hunting in areas with a sparse ground layer
- reduce populations of fire-sensitive transformer weeds
- reduce the risk of Bell Miner Associated Dieback through removal of midstorey nesting habitat

In addition to reducing the overabundant midstorey, the restoration of regular fire is also expected to:

- restore and maintain appropriate soil nutrient ratios, soil acidity and soil microbiota for open forest plant communities
- maintain open forest plant populations through restoring regular seedling recruitment opportunities and stimulating new growth

6.2.3.2 Rationale for planned burns to reduce bushfire risk

Given the extreme flammability of Australian open forests, *total* fire-exclusion is an unrealistic and undesirable management goal. The choice is not *whether or not these forests will burn*, but rather *whether they burn as uncontrolled wildfires or as planned burns under controlled conditions*.

Planned burns are the primary tool for reducing the risk of high intensity bush fire worldwide, and provide an invaluable tool for reducing the likelihood of high intensity bush fire and peat fires within open forest in the region. The overriding premise of planned burns for hazard reduction is to pre-emptively reduce fuels under controlled conditions (e.g. mild weather and coordinated deployment of fire suppression resources), rather than allowing accumulated fuels to ignite under severe fire weather and cause severe and uncontrollable crown fires.

By reducing the load and vertical continuity of fuels, planned burns reduce the rate of spread, flame height and intensity of bush fires [107] – keeping fire on the ground and preventing crown fires (**Figure 19**) - thereby enabling easier bushfire control and suppression and reducing impacts to biodiversity. Importantly, hazard reduction burning can only realistically be expected to reduce, rather than eliminate, bush fire risk. Fuel in some forest types can recover to a level capable of sustaining fire, albeit at relatively low intensity, within a few years of being burnt, especially in extreme fire weather. Accordingly, to improve effectiveness, planned burning programs must also aim to maintain a *mosaic* of low to moderate fuel levels across the landscape. This patchwork of fuel ages causes the bushfire to slow or self-extinguish wherever it encounters recently burnt areas, greatly assisting bush fire suppression. In order to halve bush fire risk, planned burning should aim to treat 7-10% per annum of fire-prone vegetation over a given area [129].

Numerous Australian and international studies have demonstrated that planned burns are effective in reducing wildfire severity and spread [130–133], including during the 2019-20 wildfires [134,135]. And recent studies provide empirical evidence that the removal of historical Aboriginal burning exacerbates bush fire risk and severity [136,137]. However, the effectiveness of planned burns often declines with time since fire and during severe fire weather [134,138]. Several studies have found that crown fire likelihood is low up to c. 5 years post-fire, peaks at 10-20 years post-fire and then declines [139,140]. While this is often used as an argument against the need for hazard reduction burns[140], this ignores the importance of maintaining a landscape mosaic of different age classes of habitat and fuel across the landscape.

Firstly, numerous studies have shown that, a mosaic of fuel-ages can reduce fire spread and severity across the landscape without the need to maintain all vegetation in a fuel reduced state [131,141,142]. Secondly, keeping sclerophyll forests in a long-unburnt state to reduce crown fire probability will likely come at the expense of open forest biodiversity, especially species dependent on early successional habitats (see Section 5.2 'Ecological consequences of fire exclusion' above).

Planned burns can also increase protection of fire-sensitive rainforest. A recent review of prescribed burning in the Nightcap National Park [14], identified the value of prescribed burning to reduce wildfire risk to rainforest biodiversity…

> *'areas of wet sclerophyll forests… and dry sclerophyll communities also have strategic value in terms of risk mitigation for adjacent and intermixed rainforest communities. Research elsewhere indicates that prescribed burning in sclerophyll communities immediately adjacent to rainforest has highest potential to mitigate the spread of unplanned fires into rainforest, compared with treatments dispersed more generally across landscapes (e.g. King et al. 2008).* [14]'

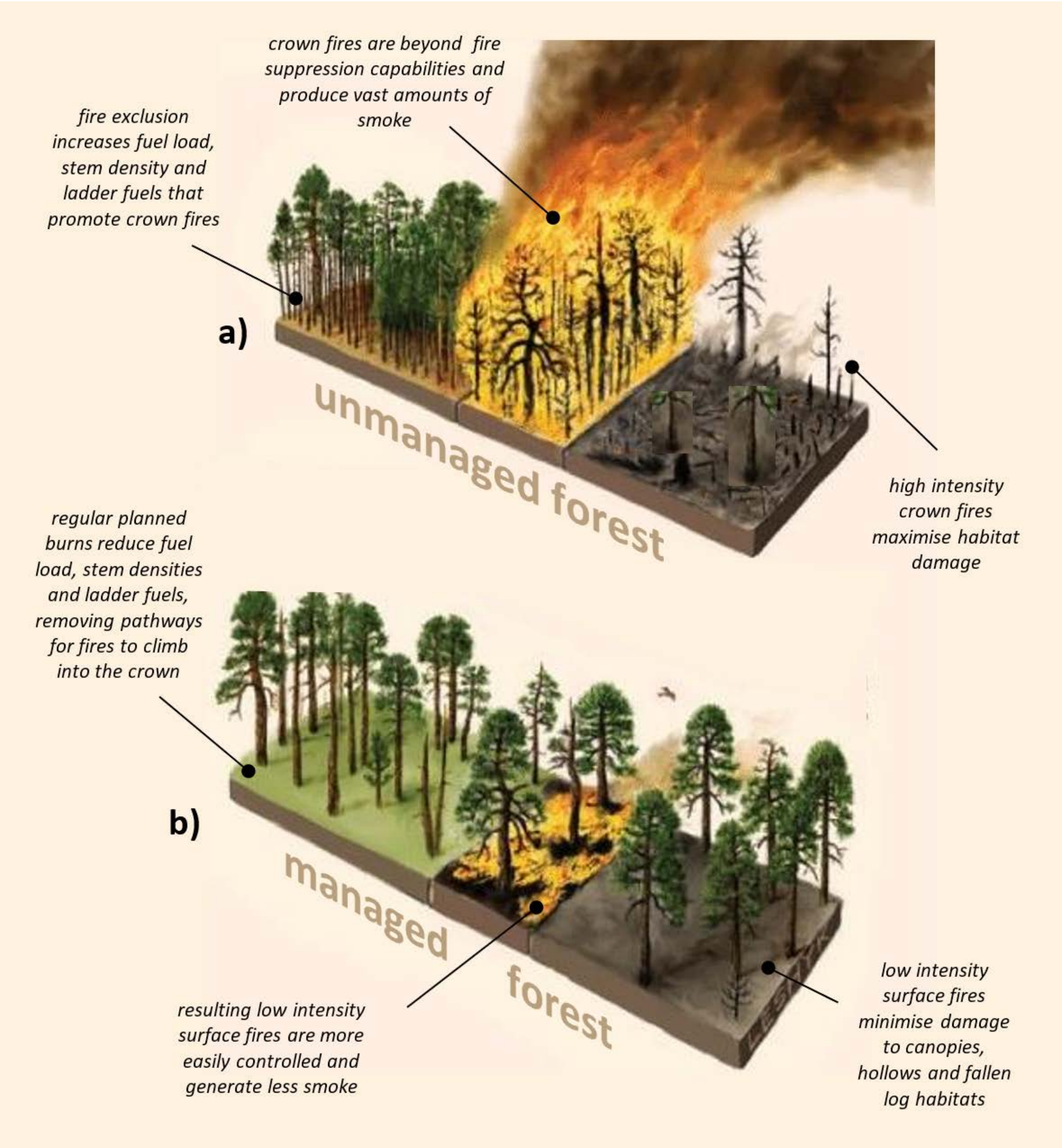


Figure 19. *Comparison of wildfire behaviour and effects in a) fire-excluded forests and b) forests managed with planed burns (adapted from 143).*

Planned burning also provides a crucial tool to minimise the likelihood of destructive peat fires. Bush fires typically occur during prolonged dry periods, which often also coincide with peat soils being exposed by lowered water tables. However, a planned burn can reduce fuels above peat soils when they are protected by a high-water table, thereby minimising peat fire risk in subsequent fire seasons.

6.2.4 Policy support for restoring Good Fire in the Northern Rivers

***Table 3**. Biodiversity strategies, management plans and guidelines relevant to the Northern Rivers and provisions relating to the maintenance and restoration of ecological processes, including fire.*

Strategy or Plan	Relevant Provisions
Ballina Shire Biodiversity Strategy 2023	Collaborate with relevant stakeholders to implement the Ballina Shire Koala Fire Management Plan (Action 1.3.5) Investigate opportunities to manage fire regimes on Council reserves in partnership with fire agencies seeking to minimise bushfire risk (3.2.5). Add biodiversity assets that are threatened by altered fire regimes to the Far North Coast Bush Fire Risk Management Plan to leverage agency assistance with burn implementation.
Byron Shire Biodiversity Conservation Strategy 2020-2030 [47]	The BCS identifies the restoration of fire as an important strategy for conserving the open forest values of the Shire . Identify priority open forest ecosystems requiring restoration through the reintroduction of fire. (Action 4.4) Raise community awareness of how planned fire in open forest ecosystems can help conserve biodiversity, re-invigorate Aboriginal cultural practices, improve community bush fire safety and reduce greenhouse gas emissions. (Action 2.5)
Byron Shire Bush Regeneration Guidelines (BSC 2010)	*'altered fire regimes'* are listed as a management issue that should be considered as part of the minimum information requirements for a bush regeneration plan. To *'understand the role of fire in managing the vegetation types at a site'* is listed as a requirement for effective bush regeneration.
Living with Fire in NSW National Parks (2012–2021) [144]	*Manage fire regimes in reserves to maintain and enhance biodiversity (Objective 3)* *to assist other fire agencies, land management authorities and landholders in developing fire management practices that contribute to conserving biodiversity and cultural heritage across the landscape. (Objective 5)*
Far North Coast Bushfire Risk Management Plan [145]	*Implement appropriate fire regimes (various ecological values)*
Northern Rivers Regional Biodiversity Management Plan [125]	Maintain and improve biodiversity and ecological processes by the rehabilitation and management of native vegetation across all land tenures (Objective 1). Protect vegetation communities, ecosystems and habitats from inappropriate fire regimes (Recovery objective 4)
National Standards for the Practice of Ecological Restoration in Australia [128]	Ecological restoration practice is based on an appropriate local native reference ecosystem with historical structure, composition and function (i.e. fire regime) (Principle 1) Recovery of ecosystem attributes is facilitated by identifying clear targets, goals and objectives [based on reference structure, composition and function] (Principle 3) Historical fire regimes (disturbance regimes) are a key component of ecosystem function, which in turn is a key ecosystem attribute that must be restored to achieve a high level of recovery.
Australia's Biodiversity Conservation Strategy 2010-2030 (NRMMC 2010)	Maintain and re‑establish ecosystem functions (Objective 2.2).

7 More Information

The following links have further information relating to the restoration of Good Fire.

Southeast Queensland Planned Burn Guidelines
https://parks.des.qld.gov.au/__data/assets/pdf_file/0030/305688/Bp2005-SEQ-planned-burn-guidelines.pdf

Jagun Alliance Aboriginal Corporation

https://www.jagunalliance.org.au/

Wildsite Ecological Services

http://www.wildsite.com.au/

Firesticks Alliance Indigenous Corporation

https://www.firesticks.org.au

Queensland Fire and Biodiversity Consortium (QFBC)

https://www.fireandbiodiversity.org.au/

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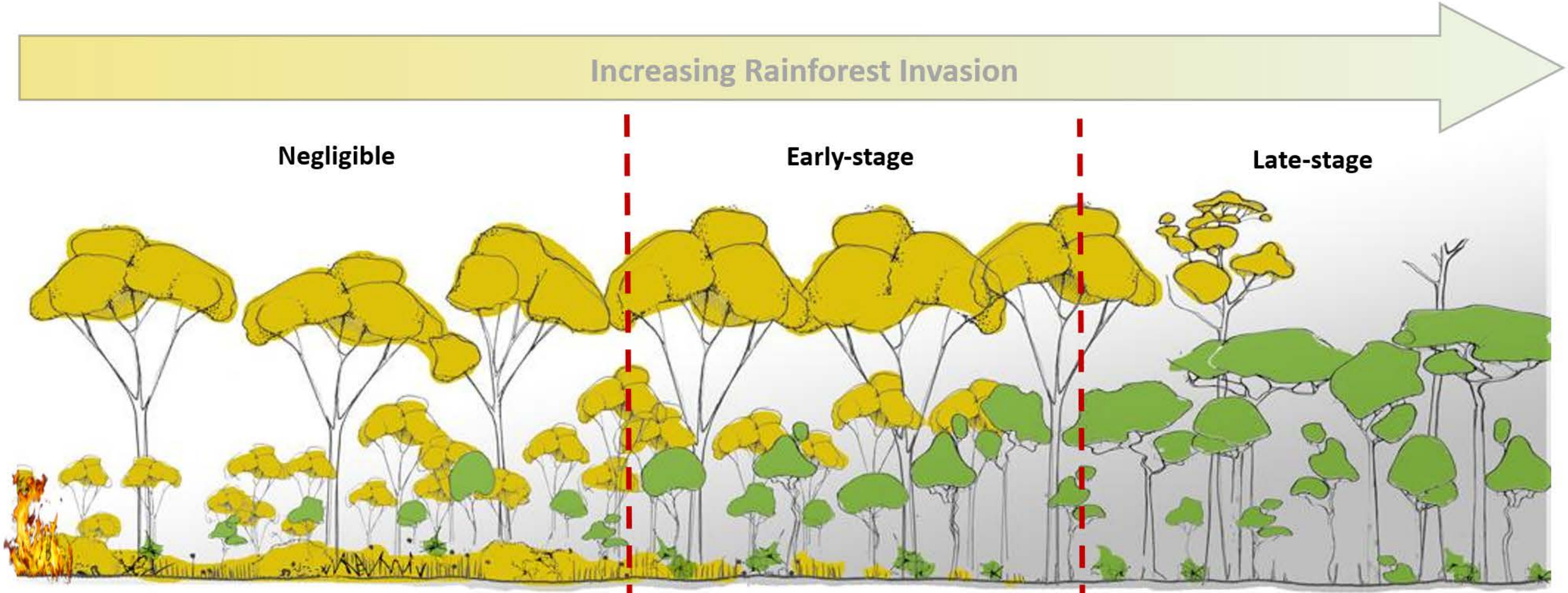
9 Appendices

Appendix A. *Summary of ecological consequences of rainforest invasion on open forest biodiversity. Yellow – open/sclerophyll forest vegetation: canopy trees (Eucalypts, Paperbarks, Brush box), midstorey trees/shrubs (Wattles, She-Oaks, Ti Tree) and shade-intolerant ground layer shrubs, grasses & ferns. Green – shade-tolerant rainforest pioneers and transformer weeds*



Negligible

Plants (open forest)

- understorey plants thrive in high light, suitable soil chemistry and soil microbial conditions
- understorey and canopy flora recruit new seedlings after fire
- canopy trees thrive with suitable soil chemistry, microbial conditions and adequate soil water
- canopy trees not affected by Bell Miner Dieback without dense midstorey nesting habitat

Animals (open forest)

- understorey animals have abundant forage, shelter and nesting resources in dense understorey
- midstorey flying animals have ample room to move beneath canopy
- canopy animals have abundant hollows, nectar and foliage of open forest canopy trees

Early-stage

Plants (open forest)

- understorey plants decline in deep shade
- understorey plants cannot recruit new seedlings in shade

Animals (open forest)

- understorey animals decline without forage, shelter and nesting resources previously provided by dense understorey plants
- midstorey flying animals decline without room to move beneath canopy

Late-stage

Plants (open forest)

- canopy trees cannot recruit new seedlings in shade
- premature dieback of canopy trees from altered soil chemistry, soil microbes, water availability and Bell Miner Associated Dieback

Animals (open forest):

- loss of fauna dependent on hollows, nectar and foliage of open forest canopy trees

PROPERTY ASSESSMENT METHODS

This Appendix provides property assessment methods for preparing a *Good Fire Restoration Plan*, including the identification of:

B1. Environmental Planning Overlays

This assessment is required to identify environmental protection overlays on the property that influence potential burn approval pathways, and involves four main steps:

a) Access the online map viewer for the relevant Council (e.g. https://www.byron.nsw.gov.au/Services/Online-map-tools)

b) Extract the following data layers for the property

   i) Conservation Zones (e.g. C2, C3; Local Environment Plan)

   ii) SEPP (Resilience & Hazards) 2021 – Coastal Wetlands

   iii) SEPP (Resilience & Hazards) 2021 – Coastal Wetlands (100m buffer)

   iv) SEPP (Resilience & Hazards) 2021 – Littoral Rainforest

   v) SEPP (Resilience & Hazards) 2021 – Littoral Rainforest (100m buffer)

   vi) SEPP (Resilience & Hazards) 2021 – Coastal Environment Area

   vii) SEPP (Resilience & Hazards) 2021 – Coastal Use Area

c) Identify any Biodiversity Conservation Trust (BCT) Conservation Agreement Areas (as identified in relevant BCT property management plan or supplied by BCT)

d) Produce final planning overlap map and table showing all relevant overlays.

B2.Vegetation types and their relationship to fire

This assessment is required to prepare a brief description, table and map describing the major vegetation classes found on the property, and involves four main steps:

a) Downloading the vegetation dataset (GIS)

b) Desktop classification of vegetation to fire relationship and fire class

c) Ground-truthing survey to assign forests to fire class (subformation)

d) Produce final vegetation map and table with fire classes and recommended fire frequency

A) Downloading vegetation layer (GIS)

Where available, vegetation mapping for individual Local Government Areas in the Northern Rivers can be downloaded from the SEED data portal, or obtained directly from the relevant Council. For example, the Byron Shire Council vegetation mapping dataset (ByronVeg2021_VIS5109) can be downloaded from the SEED data portal (https://datasets.seed.nsw.gov.au/dataset/byron-lga-vegetation-2021-vis_id-5109).

B) Desktop classification of vegetation to fire relationship & class

Assign the fire relationship for all vegetation polygons using **Table B1** below.

Table B1. *Fire relationship of vegetation formations in the Northern Rivers.*

Vegetation Formation (PCT_form)	Fire Relationship	Fire Class*
Freshwater Wetlands	Fire dependent	Heathlands
Heathlands	Fire dependent	Heathlands
Forested Wetlands	Fire dependent	*Swamp Sclerophyll Forest**
Dry Sclerophyll Forests	Fire dependent	*Dry Sclerophyll Forest**
Wet Sclerophyll Forests	Fire dependent	*Wet Sclerophyll Forest**
Rainforest	Fire sensitive	Rainforest
Saline Wetlands	Fire sensitive	Saline Wetlands
Exotic, Rainforests (Derived), Grassland, Unassigned	Exclude from assessment	NA

* temporary fire classes that need to be refined to sub-formation by ground truthing.

C) Ground-truthing survey to assign forests to fire class (subformation)

Prepare field maps showing all temporary fire classes for the property (i.e. Fire Class *= Dry Sclerophyll Forests*, Swamp Sclerophyll Forest* or Wet Sclerophyll Forests**.

In the field, ground truth each mapped forest polygon and assign to *fire class* (sub-formation) using the key to formations (**Appendix C**).

D) Produce final vegetation map with fire classes and recommended frequency

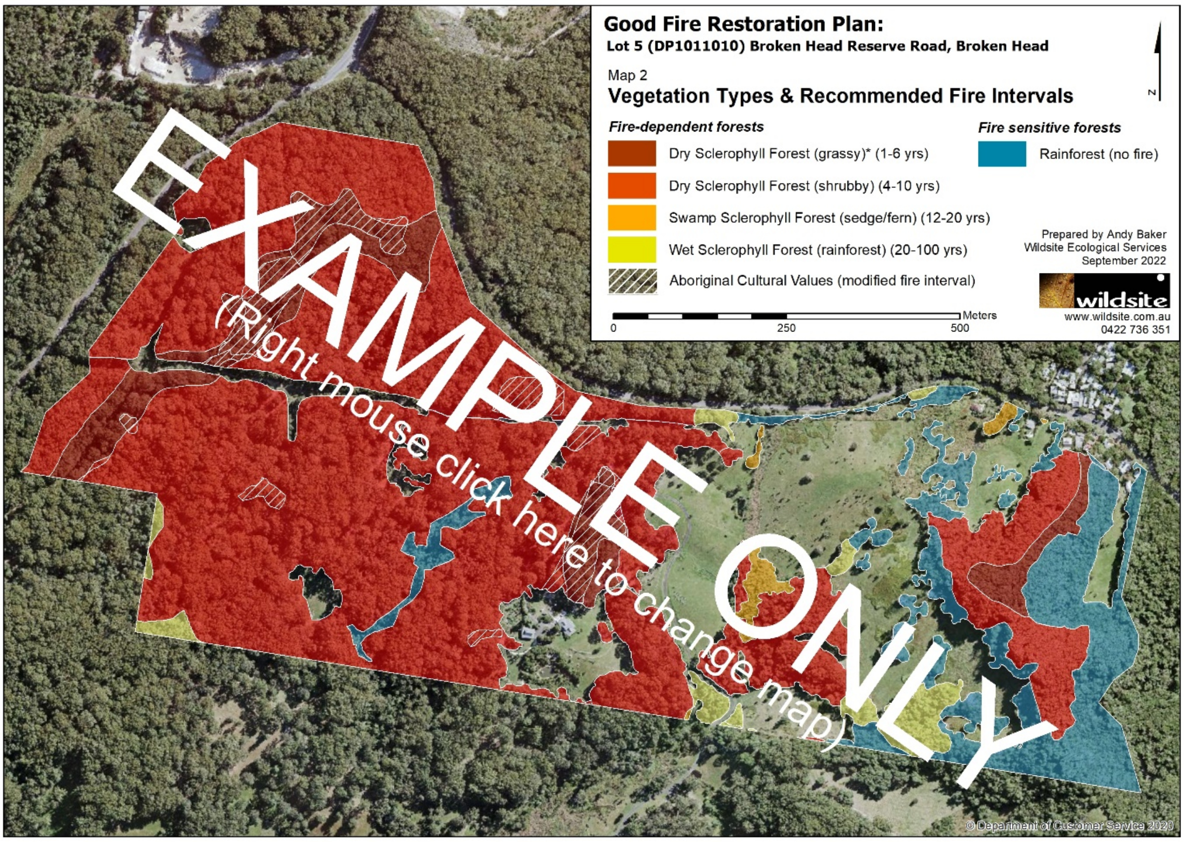
Using finalised *fire class,* code all polygons with the corresponding minimum and maximum recommended fire frequency (separate fields; **Table B2**).

Table B2. *Vegetation classes and their recommended fire intervals [11].*

Vegetation Classes	Recommended Fire Interval (years)
Heathlands	
coastal	6 - 12
montane	20 - 50
Dry Sclerophyll Forest	
grassy	1 - 6
shrubby	4 - 10
Swamp Sclerophyll Forest	
grass / shrub	6 – 20
heathy shrub	8 – 12
sedge / fern	12 -20
Wet Sclerophyll Forest	
grassy	3 – 5
fern / shrub	8 – 20
rainforest understorey	20 – 100
Rainforest, Saline Wetlands	No Fire

The final vegetation map should show the following (see example below):

- Vegetation classes grouped under **fire-dependent ecosystem** classes (e.g. Dry Sclerophyll Forest (Grassy), Swamp Sclerophyll Forest (sedge / fern)) and **fire-sensitive ecosystem** classes (i.e. rainforest, mangroves, salt marsh).
- Recommended fire intervals for each ecosystem.
- Cultural value overlay of modified fire intervals (e.g. grassy pathways) identified by cultural survey.



B3. Threatened species and their relationship to fire

This assessment is required to provide tables of threatened flora, fauna and ecological communities (BC Act; EPBC Act) with a moderate-high likelihood of using the habitat on the property, and involves three main steps:

a) Search for threatened species in the NSW BioNet Atlas.
b) Select records that occur within 5km radius of property.
c) Assign threatened species to fire~habitat association and present in tables.

A) Search for threatened species in the NSW BioNet Atlas

Undertake a BioNet Atlas search for threatened flora, fauna, fungi and communities in and around the property (c. 15km x 15 km).

https://www.environment.nsw.gov.au/atlaspublicapp/UI_Modules/ATLAS_/AtlasSearch.aspx

B) Select records that occur within 5km radius of property

Using GIS Software, select all records with 5km radius of the property boundary.

C) Assign threatened species to fire~habitat association and present in tables

Assign threatened species to fire~habitat association using **Appendix D**.

Final tables should be inserted into Appendix A of the GFRP and show the following (see template for example):

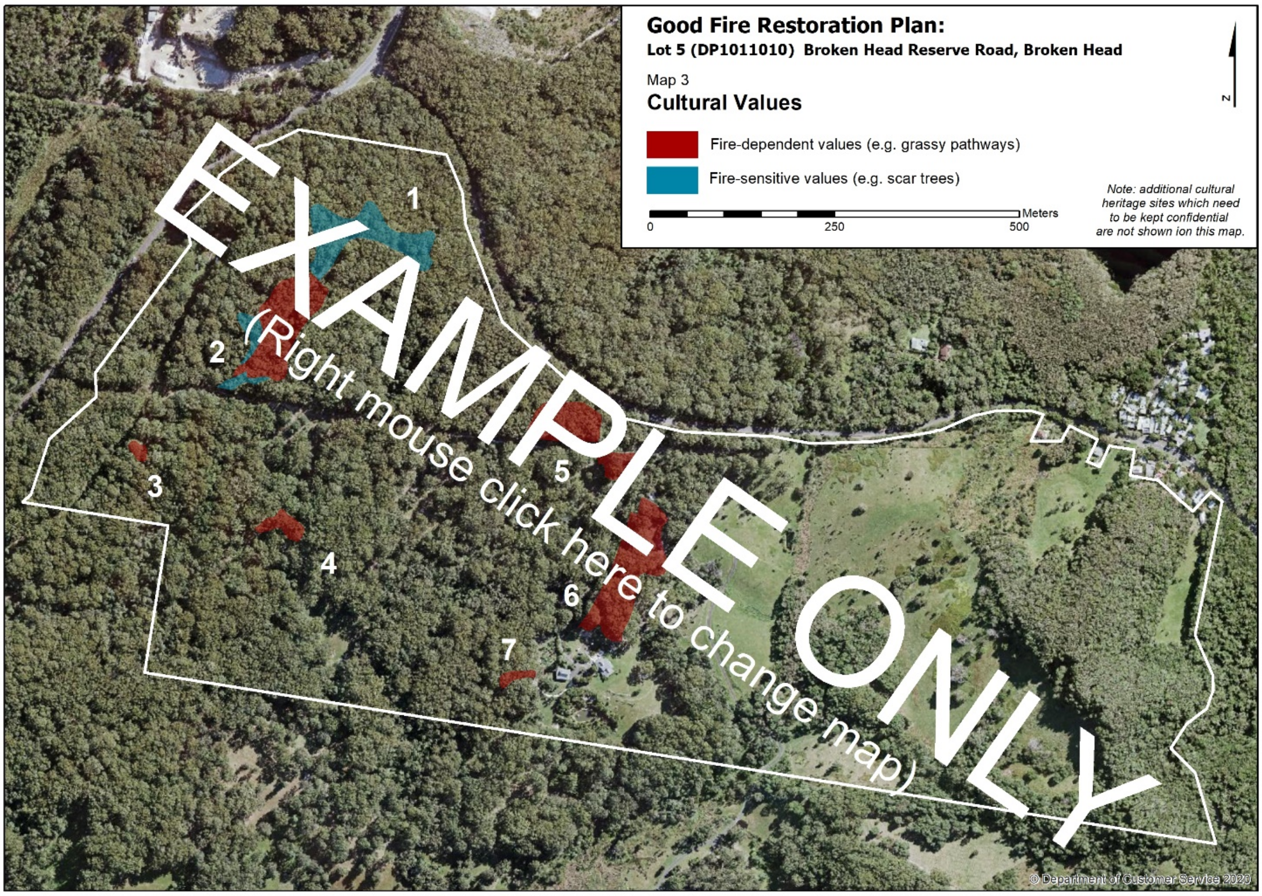
- Separate tables for each fire~habitat group.
- Values grouped by threatened communities, flora and fauna.
- Status under NSW BC Act and EPBC Act.
- Fire-dependent habitat association.

B4. Aboriginal Cultural Values & Issues

This assessment is required to identify Aboriginal Cultural Values on the property and any fire-related issues that may have a positive or negative affect on these values. The assessment must be undertaken by a suitable Aboriginal knowledge holder, who are often best nominated by the relevant Local Aboriginal Land Council (LALC). A list and map of relevant LALCs in the Northern Rivers can be found here https://www.dcceew.gov.au/sites/default/files/documents/northern-rivers-appendix-14.pdf.

The assessment involves three main steps:

a) Conduct a fire and cultural heritage assessment of the property
b) Identify whether cultural heritage site information i) can be shared or ii) needs to be kept confidential
c) Provide an overview of any known (if approved) or suspected cultural values, including display on a map. Map should show cultural values that are:
    a. fire-dependent (e.g. need regular fire to maintain value; campsite) or
    b. fire-sensitive (e.g. should be protected from fire; scar tree)



B5. Fire Interval Status

This assessment is required to identify the fire interval status of fire-dependent vegetation on the property, including areas threatened by altered fire frequency. The assessment involves a GIS analysis that compares *modern fire history* and *recommended fire intervals* for mapped native vegetation. The assessment involves three main steps:

d) Acquire fire history datasets (NPWS & RFS)
e) Prepare fire history & vegetation datasets
f) Undertake fire interval analysis and display results

A) Acquire fire history datasets (NPWS & RFS)

Dataset Name	Custodian	Process
• *NPWS Fire History - Wildfires and Prescribed Burns*	NSW National Parks and Wildlife Service (NPWS)	Download from the SEED data portal https://datasets.seed.nsw.gov.au/dataset/fire-history-wildfires-and-prescribed-burns-1e8b6
• *WildfireHistory* • *HRWorksActualArea*	NSW Rural Fire Service (RFS)	Email request to RFS Data Analyst kristen.bartell@rfs.nsw.gov.au

B) Prepare fire history & vegetation datasets

Using GIS software:

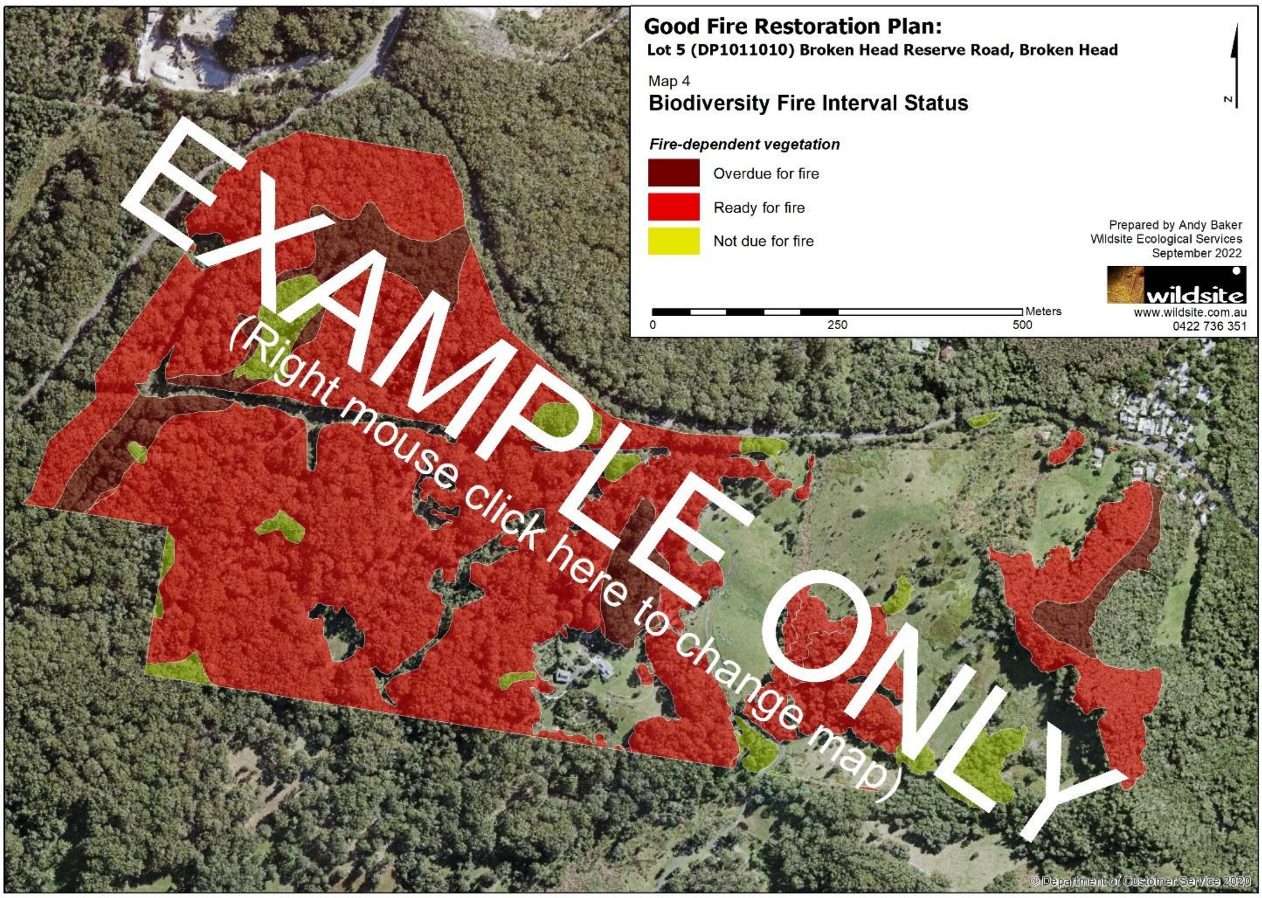
- Clip all fire history datasets to the LGA boundary.
- Union all fire history datasets into a single layer.
- Merge all fires that occur in the same year.
- Select fire with most recent fire year and clip/discard all intersecting areas from previous fire year polygons. Repeat for all polygons from youngest to oldest (fire year).
- Calculate 'time since fire' by subtracting 'fire year' from current year.
- Union fire history and vegetation dataset (coded with recommended fire interval) into a single layer.

C) Undertake fire interval analysis and display results

In the dataset attribute table, calculate 'fire interval status' as follows:

1. '***Overdue For Fire***' equals all polygons where ***"time since fire" ≥ 'maximum fire interval'***
2. ***'Ready For Fire'*** equals all polygons where ***"time since fire" < 'maximum fire interval' AND "time since fire" ≥ 'minimum fire interval'***
3. ***'Not Ready For Fire'*** equals all polygons where ***"time since fire" < 'minimum fire interval'***

Analysis results should be displayed on a map and graph (see example below). The map and graph should show all fire-dependent vegetation using the classes: Overdue for fire; Ready for fire, or: Not ready for fire.



B6. Open-forest condition & Good Fire Restoration Areas

This assessment is required to provide a map and description of open-forest condition across the property.

A) Site assessment to assign open-forest condition classes

Using the final property vegetation map as a baseline for reference condition, broadly map open-forest condition using the *Open-forest Condition Classes* (**Appendix E**) and Forest Health Indicators (**Appendix F**).

During site assessment, also:

- photograph examples of *good, moderate* and *poor* condition classes for inclusion into the Plan.
- record any transformer weeds with high potential to shade out ground layer communities.

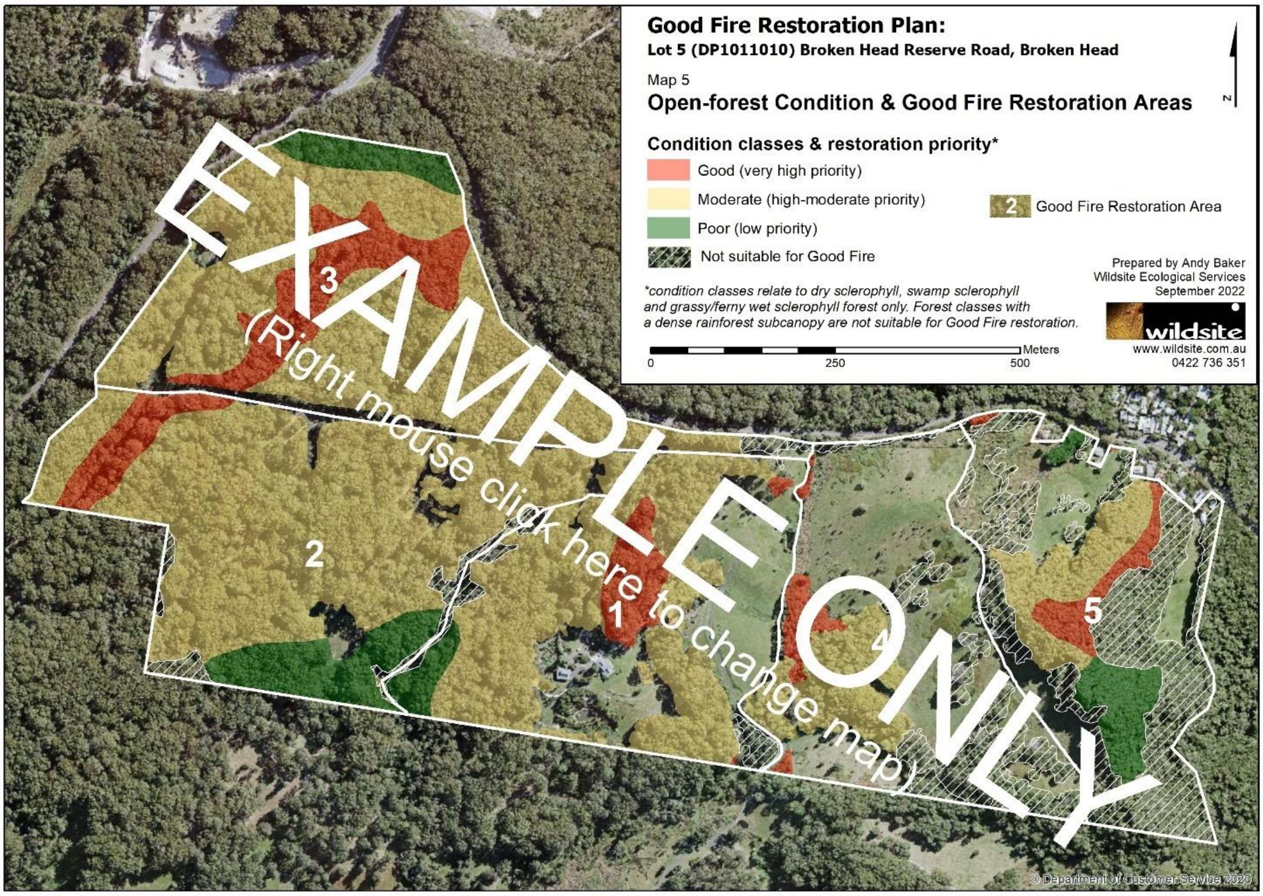
B) Identify Good Fire Restoration Areas

Divide the property into a series of management zones (Good Fire Restoration Areas) using landform, access, remnant configuration etc. to determine suitable zone boundaries.

C) Display results

Prepare a final map showing open-forest condition & Good Fire Restoration Areas that includes the following (see example below):

- Condition classes and restoration priority: *Good (very high priority); Moderate (high-moderate priority); Poor (low priority); Not suitable for Good Fire (i.e. rainforest; wet sclerophyll forest with rainforest understorey; saline wetlands)*
- Good Fire Restoration Areas (numbered)



Using text and a table, provide an overview of:

- condition classes found on the property, outlining any issues relating to midstorey density (rainforest pioneers, overabundant sclerophyll trees, transformer weeds) and density of shade-intolerant ground layer plants.
- list transformer weeds found on the property (i.e. weeds with a high capacity to eliminate ground layer plant communities through shading – often bird dispersed and shade tolerant; see **Table B3** below for common examples in the Northern Rivers).

Table B3. *Common transformer weed species in the Northern Rivers.*

Strata / Habit	Weed Species
Canopy trees	Camphor Laurel (*Cinnamomum camphora*)
	Umbrella Tree (*Schefflera actinophylla*)
	Devils Fig (*Solanum chrysotrichum*)
	Broadleaved Pepper (*Schinus terebinthifolia*)
	Cocos Palm (*Syragrus romanzoffiana*)
	Coral Trees (*Erythrina crista-gali, E x sykesii*)
Midstorey	Privets (*Ligustrum spp.*)
	Cherry Guava (*Psidium cattleianum*)
	Winter Senna (*Senna pendula*)
	Wild Tobacco (*Solanum mauritianum*)
	Lantana (*Lantana camara*)
	Ochna / Mickey Mouse Plant (*Ochna serrulata*)
Scrambler or Climber	Madeira Vine (*Anredera cordifolia*)
	Cat’s Claw Creeper (*Dolichandra unguis-cati*)
	Passionfruit (*Passiflora* spp.)
	Morning Glory (*Ipomea* spp.)
	Syngonium (*Syngonium podophyllum*)

Appendix C. *Key to sclerophyll forest fire classes (sub-formations) of NSW north coast and southeast QLD (adapted from Keith 2004; Baker 2021).*

KEY TO SCLEROPHYLL FOREST FIRE CLASSES (SUB-FORMATIONS)

1	Dominant trees* > 30m tall and with trunks vertical, very straight and lowest branches arising above halfway up trunk	8 (wet sclerophyll forest)
	Dominant trees < 35m tall and with trunks slightly to strongly leaning or crooked, and branching at less than half of their height lowest branches at or below halfway up trunk	2
2	Grows on low-lying, swampy areas of the coastal plain and floodplains. Dominated by trees able to tolerate periodic inundation or waterlogging (e.g. Paperbarks, Swamp Oak/Mahogany/Box, Forest Red Gum). Ground layer often dominated by graminoids or ferns able to tolerate periodic inundation or waterlogging (although may be limited to canopy gaps in dense stands or on rainforest-invaded sites).	3 (swamp sclerophyll forest)
	Rarely on low-lying, swampy areas of the coastal plain. Generally lacking plants able to tolerate periodic inundation or waterlogging.	5 (dry sclerophyll forest)
3	Ground layer dominated by sedges or ferns	**Swamp Sclerophyll Forest (sedge / fern)**
	Ground layer not dominated by sedges or ferns	4
4	Ground layer dominated by heathy shrubs	**Swamp Sclerophyll Forest (heathy shrub)**
	Ground layer dominated by grasses (but may include scattered heathy shrubs)	**Swamp Sclerophyll Forest (grass / shrub)**
5	Shade-intolerant heathy shrubs, grasses, sedges, herbs are observable in the ground layer* (although may be limited to canopy gaps on rainforest-invaded sites)	6
	Shade-intolerant ground layer plants are absent or too-limited to indicate historical composition (usually due to shading by invading rainforest pioneers)	7
6	Heathy shrubs and non-grass graminoids (e.g. *Lomandras*, sedges) are <u>relatively common</u> among shade-intolerant plants in the ground layer	**Dry Sclerophyll Forest (shrubby)**
	Grasses, twiners and herbs (e.g. *Themeda, Poa, Glycine, Desmodium*) are <u>relatively common</u> among the shade-intolerant plants in the ground layer, while heathy shrubs and non-grass graminoids are <u>rare or absent.</u>	**Dry Sclerophyll Forest (grassy)**
7	Occurs on poorer soils (e.g. rhyolite, sand or coarse grained metasediments).	**Dry Sclerophyll Forest (shrubby)**
	Occurs on richer soils (e.g. basalt, floodplain clays or fine-grained metasediments).	**Dry Sclerophyll Forest (grassy)**
8	Rainforest trees and shrubs form a dense subcanopy or midstorey with > 50% crown cover.	**Wet Sclerophyll Forest (rainforest understorey)**
	Rainforest trees and shrubs scattered < 50% crown cover.	9
9	Ground layer dominated by ferns (e.g. *Blechnum, Calochlaena, Doodia)*, which often form extensive colonies. Heathy shrubs (e.g. *Zieria, Hovea, Prostanthera*) may be common.	**Wet Sclerophyll Forest (fern / shrub)**
	Ground layer dominated by graminoids (e.g. *Themeda, Poa, Imperata, Entolasia, Lomandra*).	**Wet Sclerophyll Forest (grassy)**

Selecting features for assessment of tree habit and understorey composition must follow* ***Table C1.*

Table C1. Guidelines for appropriate feature selection and assessment required for reliable formation identification.

*See **Figure C2** for feature selection rationale.*

	Feature selection	Feature assessment
Dominant Tree Habit	Select the largest remnant trees in the area - preferably old-growth trees where available. Avoid younger regrowth trees or younger trees that have established during a period dominated by fire-exclusion Where a site contains no large remnant trees, large trees from adjacent areas may be used if they occur on a landscape position and soil type that closely matches the survey location.	Tree height and relative bole height (height to lowest branching) must be accurately measured Refer to **Figure C1** to confirm allocation of tree habit to appropriate formation
Understorey composition	Surveyors must search widely for potential dry sclerophyll forest indicators, targeting canopy gaps, especially along track edges or historical clearings (e.g. powerline easements).	Refer to **Table C2** to confirm whether any understorey taxa are considered reliable indicators of dry sclerophyll forests

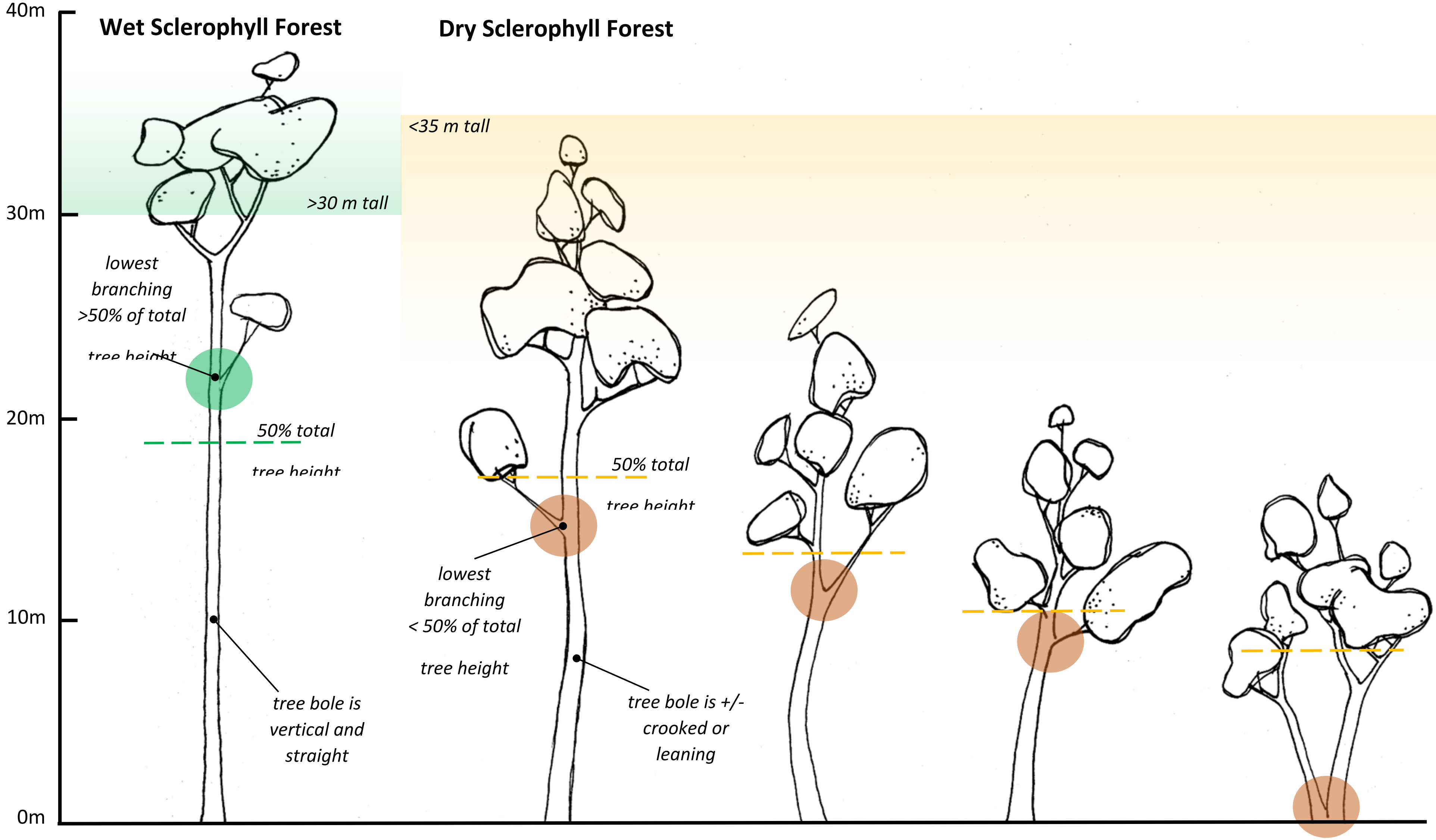


Figure C1. *Identifying features of wet- and dry-sclerophyll forest canopy tree habit.*

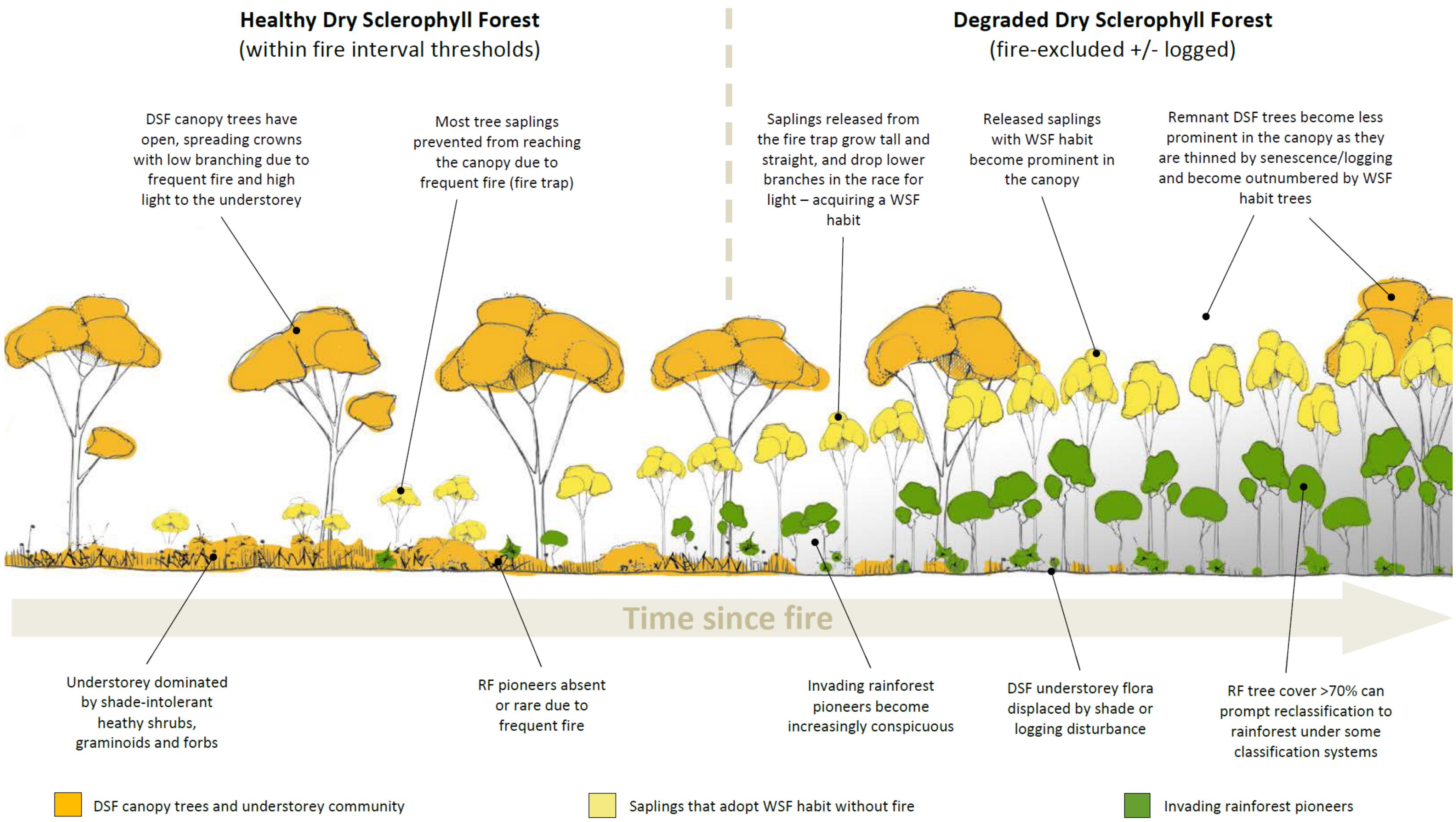


Figure C2. *Summary of changes to dry sclerophyll forest (DSF) identification features that occur with fire exclusion and logging. The changes result in the displacement of features characteristic of DSF and the increasing prominence of features typical of wet sclerophyll forest (WSF), often prompting DSF to be reclassified as WSF. Where rainforest tree cover exceeds 70%, DSF can be reclassified to rainforest under some classification systems.*

Table C2. . *Understorey flora recorded from coastal LGA's in the Northern Rivers that are considered to be highly reliable indicators of historical Dry Sclerophyll Forest due to both their: habitat association to dry sclerophyll forest, woodland, heath or grassland (RBGT 2021; Benson and McDougall 1993, 1994, 1995, 2002, 1996, 1997, 1999, 2001, 2002, 2005, 2005); and poor dispersal ability (OEH 2014). Taxa with wide dispersal ability are considered to be reliable indicators of dry sclerophyll forest only when observed in combination with other identifying taxa and features. Sensitivity to infrequent fire from the vital attributes analysis of OEH (2014) is also shown. NOTE: This list is only a subset of dry sclerophyll forest indicators in the Northern Rivers, and any additional species known to be restricted to dry sclerophyll forests, heathlands and grasslands are likely to be useful indicators.*

Scientific Name	Common Name	Dry Sclerophyll Forest Association [1 - 11]	Dispersal [13]	Sensitivity to infrequent fire [12]
Acacia myrtifolia	Red-stemmed Wattle	Grows chiefly in dry sclerophyll forest and woodland	Local	regime leads to extinction
Acacia suaveolens	Sweet Wattle	Grows in heath and dry sclerophyll forest or woodland, in sandy soil	Local	regime leads to extinction
Acacia ulicifolia	Prickly Moses	Grows in dry sclerophyll forest and woodland, usually in sandy soil.	Local	regime leads to extinction
Acacia viscidula	Sticky Wattle	Grows in dry sclerophyll forest in granite-derived soils and in heath in crevices of granite outcrops	Local	regime leads to extinction
Allocasuarina littoralis	Black She-Oak	In woodland or occasionally tall heath	Local	regime doesn't impact species viability
Aristida vagans	Threeawn Speargrass	Grows in dry sclerophyll forest.	Wide	not enough data to rank sensitivity
Aristida warburgii	A Wire or Speargrass	Open-forest, heath on sandy or gravellelly loams on sandstone or metasediments (low nutrients) and rocky ridges.	Wide	not enough data to rank sensitivity
Austromyrtus dulcis	Midgen Berry	Grows in heath or dry sclerophyll forest	Wide	regime leads to extinction
Austrostipa rudis		Grows in woodland on sandstone (subsp. Nervosa)	Wide	not enough data to rank sensitivity
Banksia oblongifolia	Fern-leaved Banksia	Grows in dry sclerophyll forest to heath	Local	regime doesn't impact species viability
Banksia spinulosa var. collina	Hairpin Banksia	Widespread in heath and dry sclerophyll forest and woodland	Local	not enough data to rank sensitivity
Billardiera scandens var. scandens	Hairy Apple Berry	Common in open eucalypt forest and woodland	Wide	not enough data to rank sensitivity
Burchardia umbellata	Milkmaids	In swamps and in heath	Local	not enough data to rank sensitivity
Caesia parviflora var. parviflora	Pale Grass-lily	Open-forest on sandy soils on sandstone, occasionally on clay soils, low–medium nutrients.	Local	not enough data to rank sensitivity
Carex breviculmis		Grows in grassland and open woodland (rather dry sites)	Local	regime doesn't impact species viability
Caustis flexuosa	Curly Wig	Grows in dry sclerophyll forest on sandy soils, derived from sandstone or granite	Local	regime leads to extinction

Scientific Name	Common Name	Dry Sclerophyll Forest Association [1-11]	Dispersal [13]	Sensitivity to infrequent fire [12]
Cenchrus caliculatus	Hillside Burrgrass	Grows on wooded hillsides on poorer soils.	Wide	not enough data to rank sensitivity
Comesperma defoliatum		Grows in wet sandy heath or swamp in sclerophyll forest	Local	regime leads to extinction
Cryptostylis erecta	Tartan Tongue Orchid	Grows in dry sclerophyll forest and heath	Wide	not enough data to rank sensitivity
Cryptostylis subulata	Large Tongue Orchid	Grows most commonly in swamp-heath but also grows in sclerophyll woodland or forest often on sandy soils	Wide	not enough data to rank sensitivity
Cymbopogon refractus	Barbed Wire Grass	Open-forest on low–medium nutrient soils	Wide	not enough data to rank sensitivity
Dampiera stricta		Heath, woodland and open-forest on sandstone	Local	regime leads to extinction
Daviesia umbellulata		Grows in heath or dry sclerophyll forest on sandy soil	Local	regime leads to extinction
Desmodium rhytidophyllum		Usually grows on sandy or stony soils in dry sclerophyll forest	Wide	regime leads to extinction
Dianella caerulea	Blue Flax-lily	Grows in heath to sclerophyll forest	Wide	regime doesn't impact species viability
Digitaria parviflora	Small-flowered Finger Grass	Grows in coastal woodland	Local	not enough data to rank sensitivity
Drosera spatulata	A Sundew	Grows in wetlands and heath	Local	regime leads to extinction
Entolasia stricta	Wiry Panic	Grows in scrub in dry areas on sandy or sandstone-derived soils	Local	not enough data to rank sensitivity
Eragrostis benthamii		Woodland on sandy soils	Local	not enough data to rank sensitivity
Eragrostis brownii	Brown's Lovegrass	Widespread in woodland and native pasture	Local	not enough data to rank sensitivity
Gahnia clarkei	Tall Saw-sedge	Open-forest and swamp on sandy soils on sandstone, alluvium; low nutrients.	Local	not enough data to rank sensitivity
Gahnia sieberiana	Red-fruit Saw-sedge	Grows in damp places and on drier hillsides in woodland	Local	regime doesn't impact species viability
Glossodia minor	Small Waxlip Orchid	heath	Wide	not enough data to rank sensitivity
Glycine microphylla	Small-leaf glycine	Open-forest and woodland generally with a grassy understorey	Local	regime leads to extinction
Gompholobium pinnatum	Pinnate Wedge Pea	Grows in dry sclerophyll forest on sandy soil, often in wet situations on the coast and adjacent ranges	Local	regime leads to extinction
Gonocarpus chinensis subsp. verrucosus		Open swamps in full sun.	Local	not enough data to rank sensitivity

Scientific Name	Common Name	Dry Sclerophyll Forest Association [1 - 11]	Dispersal [13]	Sensitivity to infrequent fire [12]
Goodenia bellidifolia subsp. bellidifolia		Open-forest; near sedgeland and swamps on sandy soil over sandstone, low nutrients.	Local	regime leads to extinction
Goodenia rotundifolia		Grows in sclerophyll woodland and forest	Local	not enough data to rank sensitivity
Haemodorum austroqueenslandicum	A Bloodroot	Grows in dry sclerophyll forest and coastal heath, often in sandy soil	Local	
Hakea actites	Mulloway Needle Bush	Grows in heath or Wallum scrub, swamp forest or dry sclerophyll forest	Local	
Hardenbergia violacea	Purple Coral Pea	Open-forest, woodland e.g. with Eucalyptus crebra, E. maculata, E. fibrosa	Local	regime leads to extinction
Hibbertia aspera	Rough Guinea Flower	In sclerophyll woodland or forests	Local	regime leads to extinction
Hibbertia diffusa	Wedge Guinea Flower	Heath and woodland on sandy loam or gravelly clay. Full sun–light shade.	Local	not enough data to rank sensitivity
Hibbertia vestita	A Guinea Flower	Grows in coastal heath or inland in dry sclerophyll forest on shallow, infertile soils	Local	regime leads to extinction
Hybanthus stellarioides	Spade Flower	Common in sandy areas in eucalypt dominated communities	Local	
Hypericum gramineum	Small St John's Wort	Grows in well-drained soils of open forest and grassland.	Local	regime doesn't impact species viability
Imperata cylindrica var. major	Blady Grass	Grows in fire-prone communities on poorer soils	Wide	not enough data to rank sensitivity
Ischaemum australe		Grows in swamps or poor sandy soils	Local	
Lagenifera stipitata	Blue Bottle-daisy	Grows in grassland, tall alpine herbfield, woodland and sclerophyll forest	Wide	not enough data to rank sensitivity
Lasiopetalum ferrugineum var. ferrugineum	Rusty Velvet-bush	In eucalypt forest and heath on coast and adjacent ranges	Local	regime leads to extinction
Laxmannia gracilis	Slender Wire Lily	Usually grows in woodland or open stony areas, on sandstone- or granite-derived soils	Local	not enough data to rank sensitivity
Lepidosperma laterale	Variable Sword-sedge	Open-forest and woodland	Local	regime doesn't impact species viability
Leptospermum microcarpum		Grows in heath and shrubby habitats	Local	not enough data to rank sensitivity
Leptospermum novae-angliae		Grows in heath and sclerophyll forest on rocky sites	Local	regime leads to extinction
Leptospermum polygalifolium subsp. cismontanum		Widespread in dry sclerophyll forest	Local	not enough data to rank sensitivity

Scientific Name	Common Name	Dry Sclerophyll Forest Association [1 - 11]	Dispersal [13]	Sensitivity to infrequent fire [12]
Leptospermum polygalifolium subsp. polygalifolium		Heath or sclerophyll forest on deep sand or in skeletal soil, usually on sandstone	Local	regime leads to extinction
Leptospermum trinervium	Slender Tea-tree	Grows in dry sclerophyll forest, heath and scrub	Local	regime leads to extinction
Leptospermum variabile		In heath	Local	not enough data to rank sensitivity
Lepyrodia scariosa	A Rush	Heath and woodland and near margins of swamps	Local	not enough data to rank sensitivity
Leucopogon lanceolatus var. gracilis	A Heath Bush	Grows mainly in coastal woodland and open forest on sandy soils	Wide	regime leads to extinction
Lindsaea linearis	Screw Fern	Open forest or heath or near swamps	Wide	regime leads to extinction
Lomandra confertifolia		Dry eucalypt forest	Local	regime doesn't impact species viability
Lomandra filiformis	Wattle Matt-rush	Grows in dry sclerophyll forest usually on well-drained often sandy or rocky soils	Local	not enough data to rank sensitivity
Lomandra multiflora subsp. multiflora		Woodland	Local	regime doesn't impact species viability
Lomatia silaifolia	Crinkle Bush	Widespread in heath, sclerophyll forest and woodland	Local	regime leads to extinction
Melaleuca sieberi		Grows in wet heath	Local	regime leads to extinction
Micrantheum ericoides		Grows in heath and dry sclerophyll forest on sandy soils of low fertility	Local	regime leads to extinction
Mirbelia pungens	Prickly Mirbelia	Widespread in heath and in stony areas	Local	regime leads to extinction
Mirbelia rubiifolia	Heathy Mirbelia	Widespread in heath and sclerophyll forest on sandy soils	Local	regime leads to extinction
Monotoca scoparia		Grows in dry sclerophyll forest, woodland and heath on sandy soil	Wide	regime leads to extinction
Murdannia graminea		Woodland with grassy understorey on sandy, low nutrient soils.	Local	
Notelaea ovata		Grows in heath and forest on poorer soils	Wide	not enough data to rank sensitivity
Olearia nernstii		Grows in sclerophyll forest or open woodland	Wide	regime leads to extinction
Ozothamnus ferrugineus	Tree Everlasting	Grows in high heathy scrub on sand	Wide	not enough data to rank sensitivity
Panicum simile	Two-colour Panic	Grows in low nutrient soils in woodland or scrub	Local	not enough data to rank sensitivity
Paspalidium criniforme		Grows in woodland on shale soils	Local	not enough data to rank sensitivity
Paspalidium distans		Grows in woodland and scrub on poor soils	Local	
Paspalum orbiculare	Ditch Millet	Grows in woodland in higher rainfall areas	Local	

Scientific Name	Common Name	Dry Sclerophyll Forest Association [1 - 11]	Dispersal [13]	Sensitivity to infrequent fire [12]
Patersonia glabrata	Leafy Purple-flag	Grows in woodland and dry sclerophyll forest	Local	not enough data to rank sensitivity
Patersonia glabrata	Leafy Purple-flag	Grows in woodland and dry sclerophyll forest on sandstone and granite and coastal heath on sand	Local	not enough data to rank sensitivity
Patersonia sericea	Silky Purple-Flag	Grows in dry sclerophyll forest and heath on sandy soil	Local	regime leads to extinction
Persoonia stradbrokensis	A Geebung	In coastal heath to dry sclerophyll forest, on coastal sand, sandstone and metasediments	Wide	
Persoonia virgata	A Geebung	Dry sclerophyll forest to on siliceous soils	Wide	regime leads to extinction
Phebalium squamulosum	Scaly Phebalium	Heath and dry sclerophyll forest on sandstone	Local	regime leads to extinction
Phyllanthus gunnii		Grows in dry sclerophyll forest on rocky slopes and along river banks, frequently on sandstone	Local	regime leads to extinction
Phyllanthus hirtellus	Thyme Spurge	Common in heath and dry sclerophyll forest	Local	regime leads to extinction
Pimelea linifolia	Slender Rice Flower	Open- forest e.g. with Corymbia gummifera, Eucalyptus sclerophylla, E. piperita, Angophora costata; heath (1)	Local	regime leads to extinction
Pimelea linifolia subsp. linifolia	Slender Rice Flower	Open- forest, heath , sea cliff scrub (2)	Local	regime leads to extinction
Platysace lanceolata	Shrubby Platysace	Grows in woodland and heath	Local	regime leads to extinction
Polymeria calycina		Grows in grassy woodland	Local	regime leads to extinction
Pomax umbellata	Pomax	Dry open-forest and woodland	Local	regime leads to extinction
Prostanthera scutellarioides		Grows in dry sclerophyll forest and woodland	Local	regime leads to extinction
Ptilothrix deusta		Wet heath and dry sclerophyll forest and woodland, on sandy soil	Local	regime leads to extinction
Pultenaea retusa	Notched Bush-pea	Dry eucalypt open-forest	Local	regime leads to extinction
Pultenaea villosa	Hairy Bush-pea	Grows in dry sclerophyll forest to heath or grassland	Local	regime leads to extinction
Schizaea bifida	Forked Comb Fern	Eucalypt open-forest, scrub or heath on sandy or infertile soils	Wide	regime leads to extinction
Schoenus ericetorum	A Rush	Grows in heath and dry sclerophyll forest, on sandy soils	Local	not enough data to rank sensitivity
Stackhousia viminea	Slender Stackhousia	Grows in forest and woodland, usually in shallow soil	Local	not enough data to rank sensitivity
Tetrarrhena juncea	Wiry Ricegrass	Grows in heath on sandstone	Local	regime doesn't impact species viability

Scientific Name	Common Name	Dry Sclerophyll Forest Association [1 - 11]	Dispersal [13]	Sensitivity to infrequent fire [12]
Tetratheca thymifolia	Black-eyed Susan	Widespread in heath and dry sclerophyll forest on sandy soils	Local	regime leads to extinction
Themeda australis	Kangaroo Grass	Grassy woodlands, coastal headlands, grassland	Local	regime leads to extinction
Thysanotus tuberosus	Common Fringe Lily	Grows in dry sclerophyll forest, woodland and heath	Local	regime doesn't impact species viability
Trachymene incisa	Trachymene	Grows in sclerophyll forest and cleared areas favouring sandy soils	Local	regime doesn't impact species viability
Tricoryne elatior	Yellow Autumn-lily	Grows in sclerophyll forest, heath and woodland, sometimes in swamps on sandy loam and lateritic soils	Local	regime doesn't impact species viability
Tricostularia pauciflora		Heath	Local	regime doesn't impact species viability
Viminaria juncea	Native Broom	Swampy places and occasionally open-heath or woodland; Sandy soil over sandstone, sand dunes, low nutrient soils	Local	regime leads to extinction
Viola silicestris	Sandstone Violet	Typically found in seasonally moist sites in sclerophyllous, healthy vegetation	Local	not enough data to rank sensitivity
Xanthorrhoea fulva	Swamp Grasstree	Wet heath	Local	regime leads to extinction
Xanthorrhoea johnsonii	Johnson's Grass Tree	Usually grows in sclerophyll forest and heath in well-drained sites	Local	regime leads to extinction
Xanthorrhoea macronema		Grows in sclerophyll forest on coastal sands and ranges	Local	not enough data to rank sensitivity
Xanthosia pilosa	Woolly Xanthosia	Grows in heath and sclerophyll forest, frequently in rocky and sandy sites	Local	regime leads to decline
Xyris operculata		Damp or swampy areas, often in heath	Local	regime leads to extinction

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Appendix D. *Threatened species and their relationship to fire.*

Table D1. *Threatened species of the Northern Rivers (coastal LGAs) and the relationship of their habitat to fire. See Table D2 for habitat criteria used to assign species to fire~habitat relationship.*

Species / Community Name	Habitat fire-relationship	Fire-sensitive/dependent habitat type/feature
Endangered Ecological Communities		
Byron Graminoid Clay Heath	Fire-dependent	Heathland, dry sclerophyll forest & woodland
Coastal Cypress Pine Forest	Fire-dependent	Dry sclerophyll forest & woodland
Grey Box—Grey Gum Wet Sclerophyll Forest	Fire-dependent	Dry sclerophyll forest and woodland, wet sclerophyll forest
Littoral Rainforest	Fire-sensitive	Rainforest
Lowland Rainforest on Floodplain	Fire-sensitive	Rainforest
Subtropical Coastal Floodplain Forest	Fire-sensitive	Rainforest
Swamp Oak Floodplain Forest	Fire-dependent	Dry sclerophyll forest and woodland
Swamp Sclerophyll Forest on Coastal Floodplains	Fire-dependent	Swamp sclerophyll forest
White Box - Yellow Box - Blakely's Red Gum Grassy Woodland	Fire-dependent	Dry sclerophyll forest and woodland
White Gum Moist Forest in the NSW North Coast Bioregion	Fire-dependent	Wet sclerophyll forest
Flora		
Allocasuarina thalassoscopica	Fire-dependent	Grassy heathland.
Harnieria hygrophiloides	Fire-variable	Rainforest and wet eucalypt forest.
Acalypha (Acalypha eremorum)	Fire-sensitive	Rainforest
Arrow-head Vine (Tinospora tinosporoides)	Fire-sensitive	Rainforest
Ball Nut (Floydia praealta)	Fire-sensitive	Rainforest
Basket Fern (Drynaria rigidula)	Fire-variable	Rainforest, moist eucalypt and Swamp Oak forest.
Brown Fairy-chain Orchid (Peristeranthus hillii)	Fire-variable	Rainforest, Brush Box forest.
Brush Sauropus (Phyllanthus microcladus)	Fire-sensitive	Rainforest
Byron Bay Diuris (Diuris byronensis)	Fire-dependent	Grassy heathland.
Cliff Sedge (Cyperus rupicola)	Fire-variable	Open rocky areas near forest.
Coast Euodia (Melicope vitiflora)	Fire-sensitive	Rainforest
Corokia (Corokia whiteana)	Fire-variable	Boundaries between wet eucalypt forest and rainforest.
Cryptic Forest Twiner (Tylophora woollsii)	Fire-variable	Moist eucalypt forest, moist sites in dry eucalypt forest and rainforest margins.
Crystal Creek Walnut (Endiandra floydii)	Fire-sensitive	Rainforest
Dark Greenhood (Pterostylis nigricans)	Fire-dependent	Coastal heathland.
Davidson's Plum (Davidsonia jerseyana)	Fire-variable	Rainforest and wet eucalypt forest.
Durobby (Syzygium moorei)	Fire-sensitive	Rainforest
Fine-leaved Tuckeroo (Lepiderema pulchella)	Fire-sensitive	Rainforest

Species / Community Name	Habitat fire-relationship	Fire-sensitive/dependent habitat type/feature
Flat Fork Fern (Psilotum complanatum)	Fire-variable	Rainforest, moist eucalypt forest.
Giant Ironwood (Backhousia subargentea)	Fire-sensitive	Rainforest
Giant Spear Lily (Doryanthes palmeri)	Fire-dependent	Rocky outcrops in montane heath.
Green-leaved Rose Walnut (Endiandra muelleri subsp. bracteata)	Fire-sensitive	Rainforest
Gympie Stinger (Dendrocnide moroides)	Fire-sensitive	Rainforest
Hairy Jointgrass (Arthraxon hispidus)	Fire-dependent	Swampy areas with low canopy cover, including edges of wet eucalypt forest and rainforest.
Hairy Quandong (Elaeocarpus williamsianus)	Fire-sensitive	Rainforest
Hartman's Sarcochilus (Sarcochilus hartmannii)	Fire-dependent	Rocky outcrops in eucalypt forest and occasionally at the bases of fibrous trunks of trees, including cycads and grass-trees.
Isoglossa (Isoglossa eranthemoides)	Fire-sensitive	Rainforest
Macadamia Nut (Macadamia integrifolia)	Fire-sensitive	Rainforest
Marblewood (Acacia bakeri)	Fire-variable	Rainforest and adjacent eucalypt forest.
Minyon Quandong (Elaeocarpus sedentarius)	Fire-variable	Rainforest and wet eucalypt forest.
Missionary Nutgrass (Cyperus semifertilis)	Fire-variable	In light gaps in wet sclerophyll forest and rainforest margins.
Narrow-leaf Finger Fern (Grammitis stenophylla)	Fire-variable	Rainforest and moist eucalypt forest, usually near streams, on rocks or in trees.
Native Guava (Rhodomyrtus psidioides)	Fire-variable	Rainforest and wet eucalypt forest.
Needle-leaf Fern (Belvisia mucronata)	Fire-variable	Epiphytic or lithophytic in rainforest or along creeks in moist open forest.
Nightcap Plectranthus (Plectranthus nitidus)	Fire-dependent	Open rocky areas near forest.
Onion Cedar (Owenia cepiodora)	Fire-sensitive	Rainforest
Peach Myrtle (Uromyrtus australis)	Fire-sensitive	Rainforest
Pink Nodding Orchid (Geodorum densiflorum)	Fire-dependent	Dry Eucalypt forest.
Queensland Xylosma (Xylosma terrae-reginae)	Fire-sensitive	Rainforest
Rainforest Cassia (Senna acclinis)	Fire-sensitive	Rainforest
Ravine Orchid (Sarcochilus fitzgeraldii)	Fire-sensitive	Rainforest
Red Boppel Nut (Hicksbeachia pinnatifolia)	Fire-variable	Rainforest, moist eucalypt forest and Brush Box forest.
Red Lilly Pilly (Syzygium hodgkinsoniae)	Fire-sensitive	Rainforest
Red-flowered King of the Fairies (Oberonia titania)	Fire-variable	Rainforest, paperbark swamps and sheltered eucalypt forest.
Red-fruited Ebony (Diospyros mabacea)	Fire-sensitive	Rainforest
Rough-shelled Bush Nut (Macadamia tetraphylla)	Fire-sensitive	Rainforest
Rusty Plum, Plum Boxwood (Niemeyera whitei)	Fire-variable	Rainforests and adjacent understorey of moist eucalypt forest.
Rusty Rose Walnut (Endiandra hayesii)	Fire-sensitive	Rainforest
Scented Acronychia (Acronychia littoralis)	Fire-variable	Rainforest and tall open forest.
Scrub Turpentine (Rhodamnia rubescens)	Fire-variable	Rainforest and wet eucalypt forest.
Shiny-leaved Ebony (Diospyros yandina)	Fire-sensitive	Rainforest
Short-footed Screw Fern (Lindsaea brachypoda)	Fire-sensitive	Rainforest
Slender Marsdenia (Marsdenia longiloba)	Fire-variable	Rainforest, and adjoining eucalypt forest.

Species / Community Name	Habitat fire-relationship	Fire-sensitive/dependent habitat type/feature
Small-leaved Hazelwood (Symplocos baeuerlenii)	Fire-sensitive	Rainforest
Small-leaved Tamarind (Diploglottis campbellii)	Fire-sensitive	Rainforest
Smooth Davidson's Plum (Davidsonia johnsonii)	Fire-variable	Rainforest and wet eucalypt forest.
Smooth Scrub Turpentine (Rhodamnia maideniana)	Fire-sensitive	Rainforest
Southern Fontainea (Fontainea australis)	Fire-sensitive	Rainforest
Southern Ochrosia (Ochrosia moorei)	Fire-sensitive	Rainforest
Southern Swamp Orchid (Phaius australis)	Fire-dependent	Paperbark forest and woodland.
Spiny Gardenia (Randia moorei)	Fire-sensitive	Rainforest
Stinking Cryptocarya (Cryptocarya foetida)	Fire-sensitive	Rainforest
Sweet Myrtle (Gossia fragrantissima)	Fire-sensitive	Rainforest
Thorny Pea (Desmodium acanthocladum)	Fire-sensitive	Rainforest
Tree Guinea Flower (Hibbertia hexandra)	Fire-variable	Heath, open forest or rainforest.
White Lace Flower (Archidendron hendersonii)	Fire-sensitive	Rainforest
White Yiel Yiel (Grevillea hilliana)	Fire-sensitive	Rainforest
White-flowered Wax Plant (Cynanchum elegans)	Fire-variable	Rainforest edges, coastal shrubland, open forest and woodland.
Yellow Satinheart (Bosistoa transversa)	Fire-sensitive	Rainforest
Yellow-flowered King of the Fairies (Oberonia complanata)	Fire-variable	Rainforest, wet or dry eucalypt forests and swamp forests .
Insects		
Coastal Petaltail (Petalura litorea)	Fire-dependent	Coastal freshwater wetlands of low vegetation or around its margins.
Giant Dragonfly (Petalura gigantea)	Fire-dependent	Permanent swamps and bogs with some free water and low vegetation.
Laced Fritillary (Argynnis hyperbius)	Fire-dependent	Open swampy coastal habitat with a graminoid understorey (grasses, Lomandras). Eggs laid on food plant, the Arrowhead Violet (Viola betonicifolia).
Southern Pink Underwing Moth (Phyllodes imperialis southern subspecies)	Fire-sensitive	Rainforest
Snails		
Mitchell's Rainforest Snail (Thersites mitchellae)	Fire-variable	Rainforest and swamp forest with a rainforest understorey.
Frogs		
Fleay's Barred Frog (Mixophyes fleayi)	Fire-variable	Rainforests and wet sclerophyll forests, in leaf litter along stream banks.
Giant Barred Frog (Mixophyes iteratus)	Fire-variable	Rainforests, moist eucalypt forest and nearby dry eucalypt forest, amongst deep, damp leaf litter.
Green and Golden Bell Frog (Litoria aurea)	Fire-variable	Vegetation in and around permanent swamp and lagoons. Open habitat often maintained by fire, but also potentially by flooding/waterlogging.
Loveridge's Frog (Philoria loveridgei)	Fire-variable	Rainforest, wet eucalypt forest, and drier forests with surface water around rocky outcrops.
Olongburra Frog (Litoria olongburensis)	Fire-dependent	Paperbark swamps and sedge swamps.
Pouched Frog (Assa darlingtoni)	Fire-variable	Rainforest, moist eucalypt forest. Shelters under moist leaf litter and logs.
Wallum Froglet (Crinia tinnula)	Fire-dependent	Paperbark swamps and sedge swamps.
Reptiles		

Species / Community Name	Habitat fire-relationship	Fire-sensitive/dependent habitat type/feature
Stephens' Banded Snake (Hoplocephalus stephensii)	Fire-variable	Rainforest and eucalypt forests.
Birds		
Albert's Lyrebird (Menura alberti)	Fire-variable	Mixed rainforest and wet open forest, frequently dominated by Brush Box. Winter foraging on ridges in moist forest.
Australasian Bittern (Botaurus poiciloptilus)	Fire-dependent	Dense fringing vegetation of streams, swamps, tidal creeks and mudflats.
Barking Owl (Ninox connivens)	Fire-dependent	Eucalypt woodland, open forest and swamp woodlands. Nests in hollows of large, old eucalypts.
Barred Cuckoo-shrike (Coracina lineata)	Fire-variable	Rainforest, eucalypt/paperbark forests and woodlands.
Black Bittern (Ixobrychus flavicollis)	Fire-variable	Dense vegetation fringing streams, swamps, tidal creeks and mudflats.
Black Falcon (Falco subniger)	Fire-dependent	Woodland, shrubland and grassland.
Black-necked Stork (Ephippiorhynchus asiaticus)	Fire-dependent	Swamps, dry floodplains and open grassy woodland.
Brolga (Grus rubicunda)	Fire-dependent	Swamp margins, floodplains and grasslands.
Brown Treecreeper (eastern subspecies) (Climacteris picumnus victoriae)	Fire-dependent	Eucalypt woodlands and dry open forest.
Bush Stone-curlew (Burhinus grallarius)	Fire-dependent	Swamp Oak and paperbark woodlands
Coxen's Fig-Parrot (Cyclopsitta diophthalma coxeni)	Fire-variable	Rainforest and adjacent wet eucalypt forest.
Dusky Woodswallow (Artamus cyanopterus cyanopterus)	Fire-dependent	Woodlands and dry open sclerophyll forests. Also shrublands and heathlands.
Eastern Grass Owl (Tyto longimembris)	Fire-dependent	Treeless habitats associated with tall dense tussocks of grass including grassy plains and wet heathland. Roosts and nests in trampled tussocks of tall grass.
Freckled Duck (Stictonetta naevosa)	Fire-dependent	Large well-vegetated swamps.
Glossy Black-Cockatoo (Calyptorhynchus lathami)	Fire-dependent	Open forest and woodlands. Feeds almost exclusively on the she-oak seeds. Nests in large hollow-bearing eucalypts.
Grey-crowned Babbler (eastern subspecies) (Pomatostomus temporalis temporalis)	Fire-dependent	Open eucalypt woodlands, with tall shrubs, and an intact ground cover of grass and forbs.
Little Eagle (Hieraaetus morphnoides)	Fire-dependent	Open eucalypt forest, woodland or open woodland.
Little Lorikeet (Glossopsitta pusilla)	Fire-dependent	Dry, open eucalypt forests and woodlands. Prefer forests with short fire intervals (2.5– 4 years).
Magpie Goose (Anseranas semipalmata)	Fire-dependent	Treeless floodplains wetlands dominated by rushes and sedges. Sedgelands. Feeds on grasses, bulbs and rhizomes.
Mangrove Honeyeater (Lichenostomus fasciogularis)	Fire-dependent	Mangroves, near-coastal forests and woodlands, including eucalypt, casuarina and paperbark swamp forests and adjacent shrublands.
Marbled Frogmouth (Podargus ocellatus)	Fire-variable	Rainforest and wet eucalypt forest with a well-developed rainforest understorey.
Masked Owl (Tyto novaehollandiae)	Fire-dependent	Dry eucalypt forests and woodlands. Roosts and nests in large eucalypt hollows.
Olive Whistler (Pachycephala olivacea)	Fire-variable	Dense vegetation of eucalypt forests, rainforests, paperbarks, coastal heathlands. Nests of twigs and grass in low forks of shrubs.
Pale-vented Bush-hen (Amaurornis moluccana)	Fire-variable	Tall dense grasslands, coastal wetlands, dense shrubland, rainforest. Breeds close to water tall-grass or tangled vegetation.

Species / Community Name	Habitat fire-relationship	Fire-sensitive/dependent habitat type/feature
Powerful Owl (Ninox strenua)	Fire-variable	Dry open forest and woodland, wet open forest and rainforest - particularly with hollows and shrub layer as prey habitat. Roosts in large Eucalypt hollows.
Red Goshawk (Erythrotriorchis radiatus)	Fire-dependent	Swamp forest and woodlands on the coastal plain - along and near watercourses.
Regent Honeyeater (Anthochaera phrygia)	Fire-dependent	Dry open forest and woodland, riparian forests of River Sheoak.
Rose-crowned Fruit-Dove (Ptilinopus regina)	Fire-variable	Rainforest, moist eucalypt forest and swamp forest with fruiting rainforest trees in the understorey.
Rufous Scrub-bird (Atrichornis rufescens)	Fire-variable	Rainforest, and moist eucalypt forest with rainforest mid-storey. Forages amongst leaf litter and logs.
Scarlet Robin (Petroica boodang)	Fire-dependent	The Scarlet Robin lives in dry eucalypt forests and woodlands. The understorey is usually open and grassy with few scattered shrubs. This species lives in both mature and regrowth vegetation. It occasionally occurs in mallee or wet forest communities, or in wetlands and tea-tree swamps. Scarlet Robin habitat usually contains abundant logs and fallen timber: these are important components of its habitat. Open grassy woodlands, open forests and grasslands.
Sooty Owl (Tyto tenebricosa)	Fire-variable	Rainforests and moist eucalypt forests. Nest in very large eucalypt tree-hollows.
Speckled Warbler (Chthonicola sagittata)	Fire-dependent	Grassy eucalypt forest.
Spotted Harrier (Circus assimilis)	Fire-dependent	Grassy open woodland and native grasslands and shrublands.
Square-tailed Kite (Lophoictinia isura)	Fire-dependent	Dry woodlands and open forests.
Superb Fruit-Dove (Ptilinopus superbus)	Fire-variable	Rainforest, moist eucalypt forest and swamp forest with fruiting rainforest trees in the understorey.
Swift Parrot (Lathamus discolor)	Fire-dependent	Eucalypt forest.
Varied Sittella (Daphoenositta chrysoptera)	Fire-dependent	Eucalypt forests and woodlands.
White-eared Monarch (Carterornis leucotis)	Fire-variable	Rainforests, wet sclerophyll forests and ecotones between dense and more open forest types - particularly among dense vines.
Wompoo Fruit-Dove (Ptilinopus magnificus)	Fire-variable	Rainforest & moist eucalypt forest. Nest in dense understorey trees and palms.
Mammals		
Common Blossom-bat (Syconycteris australis)	Fire-variable	Nectivore in heathland and melaleuca swamps. Roost in subcanopy foliage of littoral rainforest.
Common Planigale (Planigale maculata)	Fire-variable	Rainforest, sclerophyll forests, heathlands, grasslands - preferring dense ground layer close to water.
Eastern Cave Bat (Vespadelus troughtoni)	Fire-variable	Predominantly dry open forest and woodland. Occasionally along cliff-lines in wet eucalypt forest and rainforest.
Eastern Chestnut Mouse (Pseudomys gracilicaudatus)	Fire-dependent	Wet coastal heath and forest - preferring dense, regenerating ground layer in the first few years following fire.
Eastern Coastal Free-tailed Bat (Micronomus norfolkensis)	Fire-dependent	Dry sclerophyll forest, woodland, swamp forests and mangrove forests. Roost mainly in tree hollows but will also roost under bark or in man-made structures.
Eastern False Pipistrelle (Falsistrellus tasmaniensis)	Fire-variable	Hunts above or just below the tree canopy of taller forests. Generally roosts in eucalypt hollows.
Eastern Long-eared Bat (Nyctophilus bifax)	Fire-variable	Rainforest, eucalypt forest (wet, dry, swamp).
Eastern Pygmy-possum (Cercartetus nanus)	Fire-variable	Rainforest, sclerophyll forest and woodland, heath. Feeds largely on nectar and pollen collected from banksias, eucalypts and bottlebrushes. Nests in tree hollows, under eucalypt bark, in shredded bark in tree forks, grass-tree skirts.

Species / Community Name	Habitat fire-relationship	Fire-sensitive/dependent habitat type/feature
Eastern Tube-nosed Bat (Nyctimene robinsoni)	Fire-variable	Rainforest and moist eucalypt forests with a well-developed rainforest understorey.
Greater Broad-nosed Bat (Scoteanax rueppellii)	Fire-variable	Mostly open sclerophyll forest/woodland habitats, but also recorded in rainforest, foraging in open space beneath canopy. Roosts in tree hollows.
Greater Glider (Petauroides volans)	Fire-dependent	Largely restricted to eucalypt forests and woodlands. Folivorous diet of eucalypt leaves and occasionally flowers. Nests in large Eucalypt hollows.
Grey-headed Flying-fox (Pteropus poliocephalus)	Fire-variable	Rainforests, open forests, woodlands, Melaleuca swamps and Banksia woodland. Canopy-feeding frugivore, blossom-eater and nectarivore.
Hoary Wattled Bat (Chalinolobus nigrogriseus)	Fire-dependent	Dry, wet and swamp sclerophyll forests, grassy woodlands and heathlands. Breeds in dead or alive hollow-bearing trees.
Koala (Phascolarctos cinereus)	Fire-dependent	Open eucalypt forest and woodland.
Large Bent-winged Bat (Miniopterus orianae oceanensis)	Fire-variable	Forages above canopy of Eucalypt forest, rainforest & paperbark forest.
Large-eared Pied Bat (Chalinolobus dwyeri)	Fire-dependent	Dry open forest and woodland. Foraging for small, flying insects below the forest canopy.
Little Bent-winged Bat (Miniopterus australis)	Fire-variable	Forages below canopy of Eucalypt forest, rainforest & dense coastal banskia scrub. Roost in caves, tunnels and sometimes tree hollows.
Long-nosed Potoroo (Potorous tridactylus)	Fire-variable	Coastal heaths, dry and wet sclerophyll forests and rainforests. Dense understorey with occasional open areas is essential part of habitat, and may include grass-trees, sedges, ferns or heath, or of low shrubs of tea-trees or melaleucas.
New Holland Mouse (Pseudomys novaehollandiae)	Fire-dependent	Heathlands, woodlands and open forests with a heathland understorey. Prefers early to mid-stages of postfire succession.
Parma Wallaby (Macropus parma)	Fire-variable	Shelters in moist eucalypt forest with thick, shrubby understorey. Forages in nearby grassy eucalypt forest.
Red-legged Pademelon (Thylogale stigmatica)	Fire-variable	Shelters in dense ground cover in rainforest, moist eucalypt forest and vine scrub. Forage in open areas on native grasses and herbs.
Rufous Bettong (Aepyprymnus rufescens)	Fire-dependent	Eucalypt forest to woodland with a dense cover of tall native grasses used for nests construction and foraging of grasses, herbs, seeds, flowers, roots, tubers, fungi and occasionally insects.
Southern Myotis (Myotis macropus)	Fire-variable	Always close to water (streams, lakes) in rainforest, open forest or treeless habitats. Roosts close to water in caves, human structures and tree-hollows.
Spotted-tailed Quoll (Dasyurus maculatus)	Fire-variable	Eucalypt forests, rainforest and coastal heathy-woodlands. Prefers dense understorey and shrub layer.
Squirrel Glider (Petaurus norfolcensis)	Fire-dependent	Blackbutt-Bloodwood forest with heath understorey in coastal areas. Require abundant tree hollows for refuge and nest sites.
Yellow-bellied Glider (Petaurus australis)	Fire-dependent	Dry and wet eucalypt forests. Dens in hollows of eucalypts.
Yellow-bellied Sheathtail-bat (Saccolaimus flaviventris)	Fire-variable	Forages over the canopy (rainforest, open forests) and treeless areas. Roosts in tree hollows, buildings and mammal burros (treeless ecosystems).

Table D2. *Habitat criteria used to assign species to fire~habitat relationship in Table D1.*

Fire Relationship	Criteria
Fire-dependent	Habitat is limited to fire-dependent formations (i.e. grasslands, sedge/shrub/heathlands, dry/swamp/wet-sclerophyll forests and woodlands)
Fire-sensitive	Habitat is limited to fire-sensitive formations (i.e. rainforest, saline wetlands)
Fire-variable	Habitat includes both fire-dependent AND fire-sensitive formations; or habitat has no particular fire-relationship.

Appendix E. *Condition classes for dry sclerophyll forest, swamp sclerophyll forest, and grass/fern/shrub wet sclerophyll forest.*

CONDITION CLASSES FOR DRY SCLEROPHYLL FOREST, SWAMP SCLEROPHYLL FOREST AND GRASS/FERN/SHRUB WET SCLEROPHYLL FOREST.

Condition Class	Good Condition	Moderate	Poor
Midstorey	• Low-moderate crown cover (<40%) of sclerophyll shrubs/trees (e.g. Wattles, Ti-tree) • Very low crown cover (<5%) of rainforest pioneers and/or fire-sensitive transformer weeds (e.g. Camphor, Privet, Umbrella Trees)	• High crown cover (>40%) of sclerophyll shrubs/trees (e.g. Wattles, Ti-tree) • Moderate crown cover (5-40%) of rainforest pioneers and/or fire-sensitive transformer weeds (e.g. Camphor, Privet, Umbrella Trees)	• Dense, +/- continuous cover (>40%) of rainforest pioneers and/or fire-sensitive transformer weeds (e.g. Camphor, Privet, Umbrella Trees)
Ground-layer	• Sunny, well-lit, with only light or patchy shade • Dense, +/- continuous cover (>70%) of *light-demanding* grass-like plants, heathy shrubs, and/or ferns • *Shade-tolerant* plants (e.g. rainforest seedlings, C3 grasses/sedges) rare or absent • High proportion of postfire resprouters	• Moderate shading is widespread, +/- localised patches of deep shade • Sparse, patchy cover (20-70%) of *light-demanding* grass-like plants, heathy shrubs, and/or ferns • *Light-demanding* plants declining in vigour • *Shade-tolerant* plants (e.g. rainforest seedlings, C3 grasses/sedges) common	• Moderate-deep shading is widespread • Dominated by seedlings of rainforest pioneers and transformer weeds • *Light-demanding* grass-like plants, heathy shrubs, and/or ferns are absent or rare
Management Priority	Very high priority for action Secure these areas from decline before moving into other areas. These areas offer the best return for effort, large areas can be secured with Good Fire alone.	High-moderate priority for action Prevent further decline in these areas, especially further loss of remnant ground layer community. High-moderate return for effort, as these should respond well to treatments, but may require interventions additional to fire in some areas (e.g. midstorey thinning).	Low priority for action These areas have very low resilience and should only be attempted once other areas have been restored. Poor return for effort, as restoration will likely be slow and require numerous interventions additional to fire (e.g. manual thinning, replanting of ground layer, weed control)

Appendix F. *Indicators of open forest health/decline in relation to fire interval (adapted from QPWS 2022). Condition indicators relate to dry sclerophyll, swamp sclerophyll and grassy/ferny wet sclerophyll forest only. Forest classes with a dense rainforest subcanopy are not suitable for Good Fire restoration.*

Key indicators of a healthy open forest (adapted from QPWS 2022)

- Midstorey trees and shrubs are sparse/scattered and not having any widespread shading effects on ground stratum plants.
- Dense, vigorous and generally continuous ground layer of shade-intolerant grasses (or grass-like plant), heathy shrubs, and/or ferns.
- In shrubby open forest, ground layer is dominated by sclerophyllous (hard leaved) shrubs and grass-like plants (e.g. banksia, pea-flowers, grass trees, lomandras and mixed sedges) with healthy foliage. Evidence of abundant flowering and seeding.
- In grassy open forest, grass clumps and/or sedges are vigorous and well formed.
- Rainforest pioneers are generally absent from dry open forest and sparse in grassy wet sclerophyll forest and swamp sclerophyll forest.

DRY SCLEROPHYLL FOREST

Dry Sclerophyll Forest with a healthy ground layer of heathy shrubs, ferns and grass-like plants. The area has not yet passed the minimum burn interval (7 years since last fire), so provides an example of understorey condition before the preferred burn window. (Bogangar)

Dry Sclerophyll Forest with a healthy ground layer of heathy shrubs, ferns and grass-like plants. This area is now ready for a burn to ensure its ongoing health. (Broken Head)

Dry Sclerophyll Forest with a healthy ground layer of grass-like plants, heathy shrubs and twiners. This area is now ready for a burn to ensure its ongoing health. (Koonyum Range)

Dry Sclerophyll Forest with a sun-drenched healthy ground layer of sedges, heathy shrubs and grass trees. This area is now ready for a burn to ensure its ongoing health. (Broken Head)

Dry Sclerophyll Forest with a healthy ground layer of heathy shrubs. This area is now ready for a burn to ensure its ongoing health. (Broken Head)

Dry Sclerophyll Forest with a healthy ground layer of grass-like plants (Lomandra, Xanthorrhoea, Lepidosperma). The deep litter layer suggests this area is now ready for a burn to ensure its ongoing health. (Koonyum Range)

Dry Sclerophyll Forest with a healthy ground layer of heathy shrubs and grass-like plants. This area is beyond the recommended interval for a burn, and the dense midstorey shrub layer suggests this area is now ready for a burn to ensure its ongoing health. (Koonyum Range)

Dry Sclerophyll Forest with a healthy ground layer of grass-like plants (Lepidosperma, Patersonia, Lomandra). This forest is now in the appropriate window for a burn to ensure its ongoing health. (Koonyum Range)

WET SCLEROPHYLL FOREST

Wet Sclerophyll Forest with a well-lit, healthy ground layer of ferns (Blechnum) and heathy shrubs (Zieria, Hovea, Leucopogon). The canopy is relatively open, with mixed age classes of dominant canopy species (Lophostemon) and scattered rainforest trees in the midstorey. The area has not yet passed the minimum burn interval (7 years), so provides an example of understorey condition before the preferred burn window. (Cabarita)

Wet Sclerophyll Forest with a well-lit, continuous ground layer of ferns (Blechnum). The canopy is relatively open, with mixed age classes of dominant canopy species (Lophostemon) and scattered rainforest trees in the midstorey. (Cabarita)

Wet Sclerophyll Forest with a moderately healthy ground layer of ferns (Blechnum, Doodia) wherever there is still ample light reaching the forest floor. Shading out of the ferns in some areas indicates that this area is now due for a burn to ensure its ongoing health. (Byron Bay).

SWAMP SCLEROPHYLL FOREST

Swamp Sclerophyll Forest with a healthy ground layer of heathy shrubs, sedges and grasses. Mixed age classes of dominant canopy species. The area has not yet passed the minimum burn interval (8 years since last fire), so provides an example of understorey condition before the preferred burn window (Bundjalung National Park).

Swamp Sclerophyll Forest with a healthy ground layer of sedges and ferns. Mixed age classes of dominant canopy species. This area is now ready for a burn to ensure its ongoing health (Angels Beach).

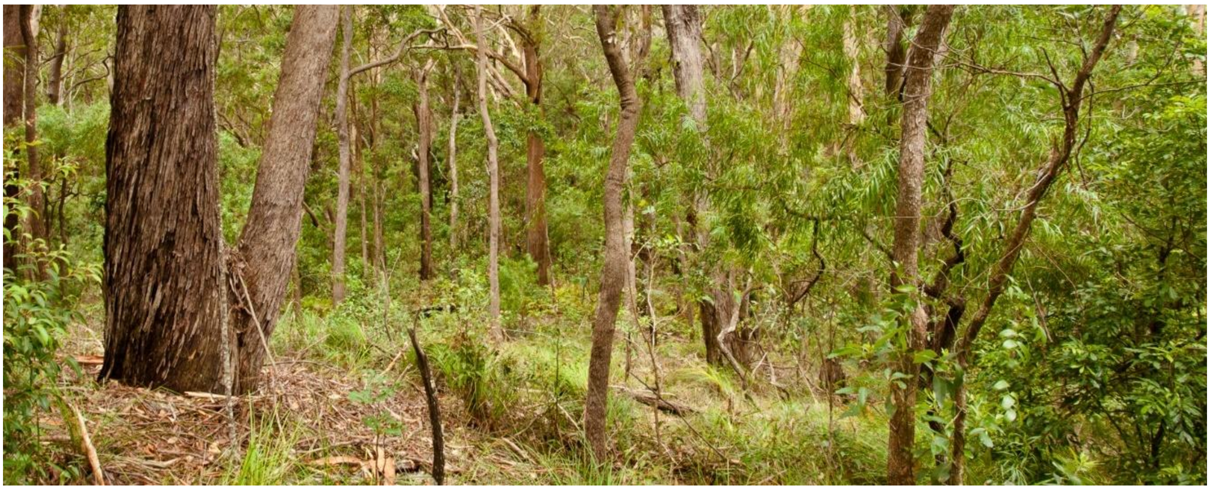
Swamp Sclerophyll Forest with a healthy ground layer of sedges, grasses, heathy shrubs and ferns. Mixed age classes of dominant canopy species. The thickening midstorey indicates that this area is nearing the optimal time for a burn (Bundjalung National Park).

Key indicators of a *declining* open forest health

(observed across a broad area; adapted from QPWS 2022)

- A dense midstorey or subcanopy of rainforest pioneers or sclerophyll trees (e.g. wattles, Allocasuarina or Eucalypt saplings) over large areas or large clumps that are having obvious shading effects on the ground layer plant communities.
- Sparse or patchy cover of shade-intolerant ground layer plants.
- The diversity of ground layer species (grasses, herbs, sedges and shrubs) has declined from previous observations, or compared to well-lit openings and track edges.
- Grasses (where present) are sparse, or clumps are poorly formed and collapsing. An accumulation of thatch (dead material) is present.
- Many heathy shrubs have dead or dying branches or sparse crowns. Grass trees have dense brown skirts or are dying in the shade.

DRY SCLEROPHYLL FOREST



Dry Sclerophyll Forest with a declining ground layer of heathy shrubs, ferns and grass-like plants. Ground layer plants are smothered by leaf litter and rainforest pioneers. This area would be a high priority for a burn before the flammable ground layer is completely lost. (Broken Head)

Dry Sclerophyll Forest with an overabundant secondary tree layer that is starting to cause the decline of the shade-intolerant ground layer of heathy shrubs, ferns and grass-like plants. This area would be a high priority for a burn (and potential thinning) before the flammable ground layer is completely lost. (Broken Head)

Dry Sclerophyll Forest with moderate rainforest invasion, where the dense litter and midstorey of rainforest pioneers has displaced the heathy ground stratum (inset shows heathy indicators found in openings). This area is a moderate priority for Good Fire, as a fire would still be possible, but additional interventions (thinning of mesics and ferns) would also be necessary to restore the heathy ground layer. (Broken Head)

Dry Sclerophyll Forest with advanced rainforest invasion causing complete displacement of the heathy/grassy ground stratum. Applying Good Fire is of lower priority in this area due to the need for additional intervention to restore this forest. (Wilsons Creek)

Dry Sclerophyll Forest with advanced rainforest invasion causing the complete displacement of the heathy ground stratum (not shown). Good fire would no longer be possible or effective in this area and additional intervention would be required to restore this forest. (Broken Head).

SWAMP SCLEROPHYLL FOREST

Swamp Sclerophyll Forest with declining ground layer of sedges under developing rainforest midstorey. This area would be a high priority for a burn before the flammable ground layer is completely lost. (Broken Head)

Swamp Sclerophyll Forest with declining ground layer of sedges under developing rainforest midstorey. This area would be a high priority for a burn before the flammable ground layer is completely lost. (Pottsville)

Swamp Sclerophyll Forest where rainforest midstorey has completely shaded out the ground layer of shrubs, ferns and grass-like plants. While a low intensity burn may still be possible, suitable ground layer species appear to be lacking and fire is unlikely to remove encroaching rainforest saplings. (Byron Bay)

Swamp Sclerophyll Forest with moderate-advanced rainforest invasion where the dense midstorey of rainforest pioneers has completely displaced the graminoid ground layer. Applying Good Fire would be of low priority wherever shade-intolerant ground layer plants are absent and additional intervention would be required to remove rainforest pioneers. (Tyagarah)

Swamp Sclerophyll Forest where rainforest midstorey has shaded out the typical ground layer of sedges and ferns. Good fire would no longer be possible or effective in this area (Ocean Shores).