

TWEED COAST KOALA FIRE MANAGEMENT PLAN



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Prepared by Wildsite Ecological Services for Tweed Shire Council.

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Executive Summary

Fire is a natural component of the Tweed Coast and plays an important role in maintaining the habitat of koalas and koala food trees. However, dramatic landuse changes have disrupted the natural fire regimes of these forests, which in turn threaten the long-term viability of remnant koala populations. While large, high intensity canopy fires have the potential to eliminate koalas from extensive tracts of forest, fire is nonetheless essential for the maintenance of koala habitat, and long-term fire exclusion can lead to irreversible habitat decline and displacement.

The major fire-management issues threatening the Tweed Coast koala include, i) high intensity bush fires killing individual koalas, ii) peat fires that cause widespread collapse of koala habitat, and iii) fire exclusion resulting in progressive koala habitat decline and displacement. Conversely, high frequency fires were found to be a relatively minor issue.

The Plan outlines four management strategies, including i) Access and Strategic Fire Breaks, ii) Hazard Reduction, iii) Bush Fire Response Strategy, and iv) Education, Monitoring & Research.

The *Access and Strategic Firebreaks* strategy outlines actions required to identify and establish new additions of on ground fire infrastructure to better manage bush fire and hazard reduction burn operations in koala habitat.

The *Hazard Reduction* strategy outlines a hazard reduction program to maintain reduced fuel loads in order to reduce bush fire severity and assist fire suppression activities. Hazard reduction burning is the main strategy recommended for reducing bush fire hazard in koala habitat, while also playing a crucial role in maintaining healthy koala habitat. To guide implementation of this strategy, standalone detailed guidelines - *Hazard Reduction Burn Guidelines for Koala Habitat on the Tweed Coast* - have also been developed under this Plan.

The *Bush Fire Response* strategy establishes a set of procedures to minimise adverse impacts on koalas and their habitat during bush fire suppression activities. A key product of the strategy is the *Koala Bush Fire Response Procedures*, a separate document that outlines key operating procedures, key contacts and responsibilities and maps to assist with wildfire suppression priority.

The *Education, Monitoring & Research* strategy outlines actions to engage private landowners in bush fire planning, increase community awareness of the important role of hazard reduction burning in bush fire safety and koala conservation, and undertake research to ensure best practices for fire management in koala habitat.



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List of Abbreviations and Prefixes

APZ	Asset Protection Zone
BFCC	Bush Fire Coordinating Committee
BFEAC	Bush Fire Environmental Assessment Code
BFMC	Bush Fire Management Committee
BFRMP	Bush Fire Risk Management Plan
BSC	Byron Shire Council
DECC	Department of Environment and Climate Change (NSW)
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (C'wlth)
FMP	Fire Management Plan (this Plan)
HR	Hazard Reduction
KAP	Koala Activity Precinct
KMA	Koala Management Area
KPoM	Comprehensive Koala Plan of Management
KRP	Koala Recovery Plan
KBFRP	Koala Bush Fire Response Procedures
LMZ	Land Management Zone
NPW Act	National Parks and Wildlife Act 1974 (NSW)
NPWS	National Parks and Wildlife Service (NSW)
NRFABCON	Northern Rivers Fire & Biodiversity Consortium
NSW	New South Wales
NSWSC	New South Wales Scientific Committee
NV Act	Native Vegetation Act 2003 (NSW)
OEH	Office of Environment and Heritage, (NSW)
OFH	Overall Fuel Hazard
QPWS	Queensland Parks & Wildlife Service
RF Act	Rural Fires Act 1997 (NSW)
RFS	Rural Fire Service (NSW)
SEPP 14	State Environmental Planning Policy 14 - Coastal Wetlands
SEPP 26	State Environmental Planning Policy 26 – Littoral Rainforest
SEQ	Southeast Queensland
SFAZ	Strategic Fire Advantage Zone
TEC	Threatened Ecological Community
TSC Act	Threatened Species Conservation Act 1995 (NSW)
TSC	Tweed Shire Council



Basis for Management

1 Introduction

1.1 The Tweed Coast Koala Habitat Study

The Tweed Coast Koala Habitat Study (Phillips *et al.* 2011) reported that the Tweed Coast koala population has undergone severe decline in recent decades and is now largely confined to three subpopulations centered on the Cudgen Lake - Kings Forest, Round Mountain - Koala Beach and Pottsville - Black Rocks areas (**Map 1a & b**). The Habitat Study concluded that the remaining koala numbers are now so low that current rates of mortality due to fire, cars and domestic dog attack are unsustainable by the population over the long-term. Without determined management, there is a very real risk that koalas could disappear from the Tweed Coast within the next 15 – 20 years.

The Habitat Study identified five key issues which must be addressed in order to reverse the trend of koala population decline on the Tweed Coast.

- Bush fire
- Incidental mortalities from road strike, dog attack and disease
- Habitat loss
- Lack of clear standards for ecological assessment
- Inadequate land use planning controls

According to the Habitat Study, high intensity bush fires during 2004 and 2009 in the Cudgen Lake - Kings Forest area were major contributors to the recent decline in the koala population on the Tweed Coast. The study recommended urgent measures be undertaken with support of all relevant stakeholders to protect koalas from high intensity bush fire.

1.2 Tweed Coast Comprehensive Koala Plan of Management

The Tweed Coast Comprehensive Koala Plan of Management (KPoM; TSC 2015a) has been prepared in accordance with State Environmental Planning Policy No. 44 – Koala Habitat Protection and is based on the findings of the Tweed Coast Koala Habitat Study. The KPoM aims to ensure a strategic and comprehensive approach to issues including:

- Habitat protection and restoration
- Management of bush fire
- Mitigation of threats from motor vehicles, dogs and disease
- Community education
- Research, monitoring and evaluation
- Resourcing and implementation

Initial management of bush fire under the KPoM involves reducing, as far as is possible, the likelihood of fire affecting areas of occupied koala habitat along the Tweed Coast until 2017.

Longer term fire management beyond 2017 will include ongoing bush fire mitigation and also the use of carefully planned prescribed burns to protect human life and property whilst ensuring the maintenance of koala habitat quality and recruitment of preferred koala food trees. This approach will be responsive to any changes in koala population status, distribution and current knowledge regarding the role of fire in maintaining ecosystem processes within preferred koala habitat.

This Plan represents the implementation of the following fire-related recommendations of the KPoM:

iii) In-order to better manage fire for koala-conservation in the long-term, Council will work with the NSW Rural Fire Service, local land managers and the Northern Rivers Fire and Biodiversity Consortium to develop additional treatment strategies for the Tweed Coast which may include:

- a) the potential for the establishment of an improved network of fire trails or strategic fire advantage zones for the specific purpose of fire management in KAPs
- b) identification of strategic locations for hazard reduction burning outside of occupied koala habitat areas

- c) development and implementation of guidelines for best-practice koala habitat management to complement RFS Hazard Reduction (HR) guidelines
- d) creation of a pre-incident plan for each Koala Activity Precinct (KAP)
- e) the identification and formalisation of a rapid response protocol for fire events within KAPs
- f) the use of a single sheet OEH-style operational bush fire plan for use by crews responding to an incident, with the sheet to include all contemporary data on koala habitat and occupancy and relevant treatments
- g) investigation into the use of ecological burning to promote regeneration of koala habitat where rainforest and mesophylllic vegetation is replacing koala habitat or where otherwise appropriate.

1.3 Legislative Context

1.3.1 Rural Fires Act 1997

Under the *Rural Fires Act 1997* (RF Act), public authorities and owners and occupiers of land have a duty to prevent bush fires occurring on or spreading from land under their management.

The RF Act facilitates a coordinated approach to fire planning and management within Fire Districts and Local Government Areas and infers responsibilities on Tweed Shire Council as a local authority. The Far North Coast Bush Fire Management Committee established under the RF Act consists of invited representatives from the NSW Rural Fire Service, Tweed, Byron & Ballina Shire Councils, NSW Fire and Rescue, NSW Farmers Association, Forestry Corporation NSW, Nature Conservation Council NSW, NSW National Parks and Wildlife Service, Crown Lands, NSW Police, NSW Roads and Maritime, and Essential Energy. The Committee meets three times per year to discuss district fire planning issues including hazard reduction burning and bush fire management.

The RF Act includes the protection of the environment as one of its objectives by requiring activities “to be carried out having regard to the principles of ecologically sustainable development described in section 6 (2) of the Protection of the Environment Administration Act 1991”. In accordance with the RF Act, Bush Fire Management Committees are required to have regard to these principles in carrying out any function that affects the environment.

1.3.1.1 FAR NORTH COAST BUSH FIRE RISK MANAGEMENT PLAN

Under the RF Act, Bush Fire Management Committees (BFMC) are responsible for the preparation of bush fire risk management plans (BFRMP). The Tweed Coast area is covered by the Far North Coast Bush Fire Risk Management Plan (2010).

The BFRMP is a strategic level document which:

- o identifies the level of bush fire risk to community and environmental assets;
- o outlines treatment strategies to manage the bush fire risk to identified community and environmental assets;
- o identifies the fire fighting authorities/land managers/agencies responsible for implementing the treatment strategies.

A BFRMP divides the planning area into four Bush Fire Management Zones to identify the fire management intent for each area (**Table 1**).

Table 1. Bush Fire Management Zones and relevance to koalas (Columns 1 & 2 adapted from BFMC 2009)

Zone	Purpose / Objective	Relevance to Koalas
Asset Protection Zone (APZ)	<p>To create safe areas for the direct suppression of bush fire immediately adjoining areas of human occupation, and highly valued infrastructure and public assets.</p> <p>To minimise bush fire impacts on undefended assets.</p>	<p>The creation and maintenance of APZs usually requires the removal and/or lopping of trees, and may directly impact koala food trees and individual koalas occupying affected trees.</p> <p>Preferred koala food trees retained or planted in existing APZs in accordance with canopy separation, groundcover and access requirements may be applicable at some sites to provide fire refuge for koalas.</p>
Strategic Fire Advantage Zone (SFAZ)	<p>To provide strategic areas of reduced fuel hazard to reduce the bush fire speed and intensity, and reduce the spot fire potential.</p>	<p>Hazard reduction burns in SFAZs may be used to:</p> <ul style="list-style-type: none"> • limit the spread and intensity of future bush fire in koala habitat; • maintain koala habitat within fire frequency thresholds. <p>High intensity hazard reduction burns may directly kill or injure koala individuals, or cause starvation through incineration of koala food tree foliage. The impact of high intensity hazard reduction burns is exacerbated if burns affect a large proportion of contiguous koala habitat, or occur at too high frequency for population or habitat recovery.</p>
Land Management Zone (LMZ)	<p>To reduce the likelihood of spread of bush fires through broad-scale mosaic burning where APZs or SFAZs are not appropriate.</p> <p>To meet relevant land management objectives (e.g. ecological management) through broad-scale mosaic burning.</p>	<p>Hazard reduction burns in LMZs may be used to:</p> <ul style="list-style-type: none"> • limit the spread and intensity of future bush fire in koala habitat; • maintain koala habitat within fire frequency thresholds. <p>High intensity hazard reduction burns may directly kill or injure koala individuals, or cause starvation through incineration of koala food tree foliage. The impact of high intensity hazard reduction burns is exacerbated if burns affect a large proportion of contiguous koala habitat, or occur at too high frequency for population or habitat recovery.</p>
Fire Exclusion Zone	<p>To exclude bush fire.</p>	<p>The temporary exclusion of fire from koala habitat areas at high risk of high frequency bush fire may assist recovery of koala populations and habitat.</p> <p>Long-term fire exclusion may adversely affect koala through suppressing recruitment of koala food trees and facilitating transition to unsuitable rainforest habitat.</p>

The Far North Coast BFRMP is currently under review, and the findings of this Plan are intended to assist the Far North Coast Bush Fire Management Committee in the development of new plan, including to:

- document important koala values as assets requiring protection from bush fire;
- outline potential treatment prescriptions for the protection of these assets; and
- also document any recommended new on-ground fire-fighting assets (e.g. APZs, SFAZs, LMZs).

1.3.1.2 NPWS FIRE MANAGEMENT STRATEGIES

The NSW National Parks & Wildlife Service has prepared Fire Management Strategies within the study area under Section 38(4) and Section 44 (3) of the RF Act, including:

- *Cudgen, Cudgera Creek, & Wooyung Nature Reserves Draft Fire Management Strategy* (2012);
- *Billinudgel, Marshalls Creek, Jinangong, & Brunswick Heads (north) Nature Reserves Draft Fire Management Strategy* (2015)

The relevant provisions of these plans are outlined in **Table 2**.

Table 2. NPWS Fire Management Strategies relevant to the study area.

Plan	Relevant Provisions
<i>Cudgen Nature Reserve Plan of Management (1998)</i>	<ul style="list-style-type: none"> • To manage fire on an ecological basis, except only where necessary to protect human life, property or the Reserve. • Manage fire consistent within fire thresholds (Kenny <i>et al.</i> 2004). • Encourage research into the ecological effects of fire in the Reserve, particularly the fire response of rare and threatened plant species. • Close contact and cooperation will be maintained with volunteer bush fire brigades, Council fire officers and State Forests of NSW. The NPWS will continue to actively participate in the Tweed Bush Fire Management Committee. • As far as possible fuel management will be carried out in cooperation with neighbours for mutual protection..." • The strategy identifies areas of koala habitat as 'long unburnt', 'too frequently burnt' and 'vulnerable to frequent fire'.
<i>Cudgen, Cudgera Creek, & Wooyung Nature Reserves Draft Fire Management Strategy (2012)</i>	<ul style="list-style-type: none"> • Aim to minimise crown scorch to protect koalas • Engage Tweed Valley Wildlife Carers to assist with post bush fire search for injured koalas. • The strategy identifies areas of koala habitat as 'long unburnt', 'too frequently burnt' and 'vulnerable to frequent fire'. • The strategy maps koala habitat metapopulation cells of Phillips <i>et al.</i> (2011)
<i>Billinudgel, Marshalls Creek, Jinangong, & Brunswick Heads (north) Nature Reserves - Draft Fire Management Strategy (2015)</i>	<ul style="list-style-type: none"> • The strategy identifies areas of koala habitat as 'long unburnt', 'too frequently burnt' and 'vulnerable to frequent fire'.

1.3.2 Rural Fires and Environmental Assessment Legislation Amendment Act 2002

The *Rural Fires and Environmental Assessment Legislation Amendment Act 2002* amends the RF Act and several environmental assessment-related Acts. This Act provides for a *Bush Fire Environmental Assessment Code* (RFS 2006) that allows for a streamlined environmental assessment process for the majority of hazard reduction works. To be approved under the Code, an activity must be consistent with the Code, the relevant Bush Fire Risk Management Plan, and comply with the *Threatened Species Hazard Reduction List* in minimising the impacts of hazard reduction activities on threatened species. With respect to the koala, the List specifies '*low intensity fire only in areas formally identified as koala core habitat or koala high use habitat*'.

For any activity which doesn't comply with the Code, an alternative approval pathway must be sought.

1.3.3 Threatened Species Conservation Act 1995

The Koala is listed as Vulnerable under the *NSW Threatened Species Conservation Act 1995* (TSC Act). The TSC Act primarily outlines an environmental impact assessment process to ensure that proposed activities do not adversely impact listed threatened species such as the koala. The biodiversity objectives of the TSC Act (Section 3) with relevance to the impact of fire on koalas are outlined in **Table 3**.

Table 3. Biodiversity objectives of the TSC Act with relevance to fire and koalas.

Objective	Relevance to the Tweed Coast koala
(d) to eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities,	High intensity, high frequency and low frequency bush fires threaten the survival of the koala. The TSC Act should ensure rigorous assessment of all proposed activities which potentially increase these threats in koala habitat areas, including the activities which increase the likelihood of bush fire, or activities which reduce the likelihood of implementing hazard reduction burns (e.g. the placement of fire-sensitive infrastructure within fire-dependent vegetation).
(f) to encourage the conservation of threatened species, populations and ecological communities by the adoption of measures involving co-operative management.	This plan seeks to adopt measures involving co-operative management.

1.3.3.1 KEY THREATENING PROCESSES

As of May 2015, 38 key threatening processes are listed under the TSC Act. Of these, one is relevant to fire and koalas, being: *High Frequency Fire Resulting in the Disruption of Life Cycle Processes in Plants and Animals and Loss of Vegetation Structure and Composition*. The importance of high frequency and low frequency fire to the Tweed Coast koala is outlined in **Section 4**.

Following amendments to Section 5A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and Section 94 of the TSC Act, any actions which lead to the operation or intensification of impacts of a listed key threatening process now require explicit consideration, in terms of whether they are likely to have a significant impact on koala populations.

1.3.3.2 KOALA RECOVERY PLAN

The koala recovery plan (KRP; **DECC 2008**) prepared under the TSC Act, identifies actions to be taken to ensure the long-term viability of the koala. In relation to reducing the impact of fires on koala populations, the KRP recommends that information on koalas and their habitat be disseminated to the relevant Bush Fire Management Committees, to assist in the development of Bush Fire Risk Management Plans. This Plan seeks to assist in the provision of this information to the FNCBFMC.

BFMCs are required to act consistently with the provisions of recovery plans for threatened species.

However, the TSC Act specifically states that actions taken under the RF Act during an emergency situation which are 'reasonably necessary in order to avoid a threat to life or property' need not be consistent with provisions in recovery plans.

ECOLOGICAL BURN APPROVAL PATHWAY

Section 91 of the TSC Act provides a potential approval pathway for ecological burns, wherein approval may be sought under licence 'to harm a threatened species, population or ecological community'. Where the burn is determined unlikely to significantly affect threatened species, populations or ecological communities, a certificate may be issued under section 95 of the TSC Act.

1.3.4 Environment Protection & Biodiversity Conservation Act 1999

1.3.4.1 NATIONAL KOALA CONSERVATION AND MANAGEMENT STRATEGY 2009–2014

While this strategy recognises the threat that inappropriate fire regimes pose to the koala, it contains no provisions specifically relevant to fire and koalas.

1.4 Scope of this Plan

The scope and content of this Plan has been guided by the Northern Rivers Fire and Biodiversity Consortium Koala Working Group. The Plan has relevance to all land managers in the study area including Tweed Shire Council, NSW National Parks & Wildlife Service, NSW Crown Lands, private landholders and emergency service organisations (NSW Rural Fire Service and Fire and Rescue NSW).

Part A of this Plan provides the background context for the management of fire in koala habitat.

Part B maps the conservation values, fire history, fire-interval status and fire management priorities.

Part C outlines the four main management strategies of the plan, including:

- i) Access & Strategic Fire Breaks;
- ii) Hazard Reduction;
- iii) Bush Fire Response, and
- iv) Education, Monitoring & Research

2 General Provisions

2.1 Overview

This Part sets out a number of preliminary matters including the:

- name of the Plan
- land to which the Plan applies
- making and commencement of the Plan
- duration of the Plan
- vision and outcomes of the Plan

2.2 Name of the Plan

This document is called the Tweed Coast Koala Fire Management Plan 2016 (hereafter referred to as “the Plan” or “this Plan”).

2.3 Land to which the Plan applies

This Plan applies to the *Southern Tweed Coast Koala Management Area* as defined in the KPoM (TSC 2015a; Map 1). This area (hereafter referred to as the “Tweed Coast”) contains the majority of the Tweed Coast koala population, and consists of approximately 12,800 ha extending along the coast southwards from Kingscliff, and generally east of the Pacific Motorway down to the boundary with Byron Shire (Map 1).

This Plan applies to land identified in Map 1 but does not apply to National Parks or Nature Reserves administered by the NSW Office of Environment and Heritage.

2.4 Making of the Plan

This Plan was prepared by Wildsite Ecological Services Pty Ltd (Wildsite) for Tweed Shire Council, based on an original scope prepared by the Northern Rivers Fire and Biodiversity Consortium Koala Working Group.

Following recognition that bush fire is a major threat to the survival of Koala populations in the Northern Rivers, the Northern Rivers Fire and Biodiversity Consortium Committee resolved to prepare a case study of a discrete coastal area in Tweed Shire and from this produce a technical guideline to inform management activities for the protection of koala habitat on the Tweed Coast. It is also envisaged that this plan will provide useful guidance for the Northern Rivers more broadly and other locations seeking to achieve similar outcomes.

The Plan has been endorsed by the Koala Connections Steering Committee, presented to the Northern Rivers Fire and Biodiversity Consortium (NRFABCON) and adopted as the action plan for the koala working group of NRFABCON.

2.5 Duration of the Plan

- i) The Plan is to remain in effect for a period of ten (10) years unless amended or superseded.
- ii) The Plan is to be reviewed at five yearly intervals; however the Plan may be reviewed at any time at the discretion of Tweed Shire Council.

2.6 Vision, Aims and Outcomes

The overarching vision of this Plan is to ensure a coordinated approach to bush fire management that ensures that the strategic and operational management of bush fire does not compromise koala populations or habitat.

This vision is intended to be articulated by way of the following aims:

- in the medium-term, the exclusion of bush fire from currently occupied areas for a minimum of 8 years (i.e. at least one koala generation), and
- a longer-term strategic response to the issue of fire that considers the influence of fire regimes on koala habitat quality and recruitment of preferred koala food trees.

The vision and aims of this Plan will be realised through the following outcomes/objectives:

- Identify the extent and nature of inappropriate fire regimes which threaten koalas
- Identify areas requiring hazard reduction burning, mechanical fuel reduction and additional fire management assets (e.g. APZ, fire management trails)
- Develop and recommend guidelines for hazard reduction burning in koala habitat
- Develop and formalise a rapid response protocol for bush fire events in koala habitat on the Tweed Coast.

2.7 Roles and Responsibilities

Responsibilities for the management of fire in koala habitat are widely distributed across the community. For the vision of the Plan to be achieved it will take the active cooperation of all stakeholders including landholders and government agencies. Each party must take a share in ensuring effective implementation of the Plan with a lead agency to facilitate this commitment. To achieve this, the Plan identifies the following roles and responsibilities:

2.7.1 Tweed Shire Council

Tweed Shire Council will be the lead authority to champion appropriate management of fire in koala habitat by:

- a) ensuring that the provisions of this Plan are integrated into all relevant areas of Council governance including strategic planning, development control (including Part 5 EP&A Act approvals), compliance, operations, asset management and communications
- b) providing appropriate training for personnel dealing with fire management issues in koala habitat
- c) implementing and encouraging on-ground works to improve the fire management in koala habitat
- d) monitoring koala populations and the effectiveness of the Plan
- e) preparing and implementing education programs
- g) supporting landholders, community interests participating in the implementation of this Plan

Council will seek the support of State and Federal government agencies in implementing appropriate fire management in koala habitat, particularly in respect of those elements of the Plan which fall outside Council's responsibility.

2.7.2 Government Fire Agencies

- i) Government agencies with responsibilities for fire management in koala habitat areas are encouraged to:
 - a) use this Plan in the discharge of their responsibilities
 - b) consult with Council on issues of mutual concern

2.8 FMP Duration & Adaptive Management

2.8.1 FMP duration

Management actions outlined in the FMP shall be maintained for a minimum period of ten years (i.e. until 2026). If fire management outcomes have not been achieved at the end of the ten year period, TSC may instruct that the duration of the FMP be extended.

2.8.2 Adaptive Management

The aims, guidelines, and recommended actions outlined in the FMP will be reviewed in light of progress reports to determine whether they remain appropriate.

The proposed management strategies may be modified in response to new research and/or monitoring. Procedures for variation to an approved FMP are discussed below.

2.8.3 Variation of an approved FMP

Variation of the existing FMP will be undertaken by submission of an amended FMP to TSC for approval. Once approved, the new FMP replaces the old one.

3 CONSERVATION VALUES

3.1 Koala values

Much of the original koala habitat on the Tweed Coast has been lost to clearing for agriculture and residential development and now occurs as fragmented remnants scattered throughout the study area, totaling 2,769 hectares (**Map 1**). The largest areas of remaining habitat and largest koala subpopulations are centered on the Cudgen Lake - Kings Forest, Round Mountain - Koala Beach and Pottsville - Black Rocks areas.

Table 4. Extent of koala habitat within the study area by habitat class and vegetation group.

Habitat / Vegetation Group	Hectares	% of total
PRIMARY HABITAT		
Coastal Forest Red Gum Open Forest to Woodland	18.2	0.7
Coastal Swamp Mahogany Open Forest to Woodland	112.8	4.1
Coastal Tallowwood Open Forest to Woodland	4.6	0.2
	135.6	5
SECONDARY HABITAT (CLASS A)		
Banksia Dry Sclerophyll Open Forest to Shrubland	51.9	1.9
Broad-leaved Paperbark / Swamp She-oak Closed Forest	114.1	4.1
Broad-leaved Paperbark + Eucalyptus spp.+/- Swamp Forest	77.2	2.8
Broad-leaved Paperbark Closed Forest to Woodland	937.2	33.8
Coastal Acacia Communities	13.5	0.5
Coastal Blackbutt Open Forest to Woodland	10.4	0.4
Coastal Pink Bloodwood Open Forest to Woodland	45.5	1.6
Coastal Scribbly Gum Open Forest to Woodland	27.3	1.0
Coastal Swamp Box Open Forest to Woodland	193.8	7.0
Swamp She-oak Closed Forest to Woodland	225.4	8.1
	1 696.3	61.2
SECONDARY HABITAT (CLASS B)		
Blackbutt Open Forest Complex	709.5	25.6
Brush Box Open Forest	228.2	8.2
	937.7	33.8
TOTAL	2 769.3	100.0

Detail of the koala habitat and population distribution on the Tweed Coast is further outlined in detail in the Koala Habitat Study (Philips *et al.* 2011).

3.2 Other Biodiversity Values

Koala habitat areas also support a range of other conservation values including significant vegetation types and important habitat for other threatened flora and fauna species. It is important that fire management actions to maintain koala populations and habitat are also compatible with the conservation of these additional values. To determine the compatibility of fire management actions, these conservation values have been broadly grouped by the relationship of their habitat to fire, including: i) fire-dependent; ii) fire-sensitive, and iii) fire-neutral.

The basis for maintaining these conservation values in the landscape is to ensure fire-regimes are compatible with maintaining suitable habitat for each group. This Plan recommends hazard reduction

burning within koala habitat areas in accordance with guidelines for the maintenance of associated vegetation groups, including the exclusion of fire from adjacent rainforest habitats. The Plan assumes that active maintenance of existing vegetation types, is likely to be broadly consistent with the maintenance of the conservation values dependent on these habitats. Importantly, it is beyond the scope of this plan to assess potential environmental impacts for individual management actions on each threatened species. Such assessments should be undertaken at the time of seeking environmental approval for each management action.

3.2.1.1 FIRE-DEPENDENT CONSERVATION VALUES

Fire-dependent conservation values are those that are associated only with fire-dependent vegetation formations, such as grasslands, sedgelands, heathlands and dry, wet and swamp sclerophyll forest. These vegetation formations are widely recognised to be fire-dependent - requiring fire to maintain their floristic and structural composition, and their place in the landscape. Those values that rely on fire-dependent habitats alone are considered to be at least indirectly fire-dependent themselves. All fire-dependent conservation values associated with mapped koala habitat are outlined in **Table 5**.

Fire regimes that maintain existing fire-dependent vegetation formations at a range of growth stages are also considered likely to broadly compliment the maintenance of these fire-dependent conservation values.

3.2.1.2 FIRE-SENSITIVE CONSERVATION VALUES

Fire-sensitive conservation values include those associated primarily with rainforest vegetation. While many rainforest species can survive occasional intense bush fire (Campbell & Clark 2006), these species and their habitats are generally considered sensitive to frequent fires (Bowman 2000), which can alter the habitat's floristic and structural composition. All fire-sensitive conservation values associated with mapped koala habitat are outlined in **Table 6**.

Fire management should aim to minimise the risk of intense wildfire affecting core areas of fire-sensitive habitats. While intense bush fire may impact rainforest edges, lower intensity HR burns in mild conditions typically self-extinguish at rainforest boundaries due to the higher humidity and the absence of suitable understorey fuels (Hoffmann *et al.* 2012; QPWS 2013). Indeed, applying cool burns to reduce fuels along rainforest boundaries is a key strategy for protecting rainforests against damage from intense bush fires.

Rainforest species often also expand their range into adjacent fire-dependent forests in between fires, where they are exposed to the prevailing fire regime. These range expansions of fire-sensitive species into adjacent fire-dependent vegetation are cyclical and are typically reversed with each returning fire. Where fire-sensitive species do spread into fire-dependent habitats, fire management should aim to maintain the original fire-dependent vegetation with regular fire, rather than exclude fire for the benefit of the transient fire-sensitive species.

Table 5. Fire-dependent conservation values (*TSC – NSW Threatened Species Conservation Act 1995; SEPP - State Environmental Planning Policy; EPBC - Environment Protection and Biodiversity Conservation Act 1999*).

Conservation Value	TSC/ SEPP	EPBC	Fire-dependent Habitat Association
High Conservation Value Vegetation			
<i>Coastal Cypress Pine Forest</i>	EEC		Dry sclerophyll forest
<i>Freshwater Wetlands on Coastal Floodplains</i>	EEC		Sedgeland and wet heathlands
<i>Subtropical Coastal Floodplain Forest</i>	EEC		Dry sclerophyll forest
<i>Swamp Oak Floodplain Forest</i>	EEC		Dry sclerophyll forest
<i>Swamp Sclerophyll Forest on Coastal Floodplains</i>	EEC		Swamp sclerophyll forests
<i>State Environmental Planning Policy 14 - Coastal Wetlands</i>	SEPP 14		Swamp sclerophyll forests, sedgeland and wet heathlands
Threatened Flora			
<i>Fraser's Screw Fern (Lindsaea fraseri)</i>	E1		Swamp forest and dry sclerophyll forest (OEH 2015).
<i>Lemon-scented Grass (Elyonurus citreus)</i>	E1		Sandy soils in wallum areas or sand dunes (OEH 2015).
<i>Pink Nodding Orchid (Geodorum densiflorum)</i>	E1		Dry sclerophyll forest (Harden 1993: NPWS 2002a).
<i>Southern Swamp Orchid (Phaius australis)</i>	E1	E	Swamp and dry sclerophyll forest (Bishop 2000, Harden 1993).
<i>Oldenlandia galioides</i>	E1		Swamp sclerophyll forest (OEH 2015)
Threatened Fauna			
<i>Bush Stone-curlew (Burhinus grallarius)</i>	E1		Nests in dry & swamp sclerophyll forests and woodlands (NPWS 2003).
<i>Eastern Freetail-bat (Mormopterus norfolkensis)</i>	V		Dry sclerophyll forest and woodland.
<i>Glossy Black-Cockatoo (Calyptorhynchus lathami)</i>	V		Dry sclerophyll forest and woodland.
<i>Little Eagle (Hieraaetus morphnoides)</i>	V		Dry sclerophyll forest and woodland (OEH 2015).
<i>Little Lorikeet (Glossopsitta pusilla)</i>	V		Dry sclerophyll forest and woodland (OEH 2015).
<i>Long-nosed Potoroo (Potorous tridactylus)</i>	V	V	Dry, wet & swamp sclerophyll forest, heathlands (OEH 2015).
<i>Olongburra Frog (Litoria alongburensis)</i>	V	V	Swamp sclerophyll forests, sedgeland and wet heathlands (NPWS 2002).
<i>Squirrel Glider (Petaurus norfolcensis)</i>	V		Dry sclerophyll forest (OEH 2015).
<i>Varied Sittella (Daphoenositta chrysoptera)</i>	V		Dry sclerophyll forest and woodland (OEH 2015).
<i>Wallum Froglet (Crinia tinnula)</i>	V		Swamp sclerophyll forests, sedgeland and wet heathlands (Barker, Griggs & Tyler 1995; NPWS 2002b).

Table 6. Fire-sensitive conservation values (*TSC – NSW Threatened Species Conservation Act 1995; SEPP - State Environmental Planning Policy; EPBC - Environment Protection and Biodiversity Conservation Act 1999*).

Conservation Value	TSC	EPBC	Fire-sensitive Habitat Association
High Conservation Value Vegetation			
<i>Lowland Rainforest on Floodplain</i>	EEC		Rainforest
<i>Littoral Rainforest</i>	EEC		Rainforest
<i>State Environmental Planning Policy 26 – Littoral Rainforest</i>	SEPP 26		Rainforest
Threatened Flora			
<i>Brush Cassia (Cassia brewsteri var. marksiana)</i>	E1		Rainforest (OEH 2015).
<i>Queensland Xylosma (Xylosma terrae-reginae)</i>	E1		Rainforest (NPWS 2002).
<i>Scented Acronychia (Acronychia littoralis)</i>	E1	E	Rainforest (NPWS 2002a; Harden 2002), and adjacent wet open forest (Floyd 1989).
<i>Spiny Gardenia (Randia moorei)</i>	E1	E	Rainforest
<i>Davidson's Plum (Davidsonia jerseyana)</i>	E1	E	Rainforest, and adjacent wet sclerophyll forest understorey (NPWS 2002)
<i>Short-footed Screw Fern (Lindsaea brachypoda)</i>	E1		Rainforest (OEH 2015).
<i>Durobby (Syzygium moorei)</i>	V	V	Rainforest (Landmark 1999; NPWS 2002; and Harden 2002).
<i>Red Lilly Pilly (Syzygium hodgkinsoniae)</i>	V	V	Rainforest (Landmark 1999; NPWS 2002; and Harden 2002).
<i>Stinking Cryptocarya (Cryptocarya foetida)</i>	V	V	Rainforest (Landmark 1999; NPWS 2002a).
<i>Thorny Pea (Desmodium acanthocladum)</i>	V	V	Rainforest (OEH 2015).
Threatened Fauna			
<i>Mitchell's Rainforest Snail (Thersites mitchellae)</i>	E1	CE	Rainforest, and adjacent swamp sclerophyll forest understorey (NPWS 2002b).
<i>Rose-crowned Fruit-Dove (Ptilinopus regina)</i>	V		Rainforest, and adjacent wet and swamp sclerophyll forest understorey (NPWS 2002).
<i>Wompoo Fruit-Dove (Ptilinopus magnificus)</i>	V		Rainforest, and adjacent wet sclerophyll forest understorey (OEH 2015).

3.2.1.3 FIRE-NEUTRAL CONSERVATION VALUES

Fire-neutral conservation values include species which utilise either: i) *both* fire-sensitive *and* fire-dependent vegetation types, or ii) vegetation types with no particular fire-relationship. Management should aim to maintain both fire-dependent and fire-sensitive habitats in the landscape. All fire-neutral conservation values associated with mapped koala habitat are outlined in **Table 7**.

Table 7. Fire-neutral conservation values (TSC – NSW Threatened Species Conservation Act 1995; SEPP - State Environmental Planning Policy; EPBC - Environment Protection and Biodiversity Conservation Act 1999).

Conservation Value	TSC	EPBC	Fire-dependent/ sensitive/neutral Habitat Associations
Threatened Flora			
<i>Basket Fern (Drynaria rigidula)</i>	E1		Rainforest, dry & swamp sclerophyll forests.
<i>Hairy Jointgrass (Arthraxon hispidus)</i>	V	V	Ecotones between rainforest and wet sclerophyll forest (OEH 2015).
Threatened Fauna			
<i>Black Bittern (Ixobrychus flavicollis)</i>	V		Mangroves, swamp sclerophyll forests (NPWS 2002).
<i>Black-necked Stork (Ephippiorhynchus asiaticus)</i>	E1		Mangroves, vegetated swamps and open grassy woodland (NPWS 2002b).
<i>Common Blossom-bat (Syconycteris australis)</i>	V		Roosts in littoral rainforest, and feeds in heathland and swamp sclerophyll forest (NPWS 2002).
<i>Common Planigale (Planigale maculata)</i>	V		Rainforests, dry sclerophyll forests, heathlands and grassy woodlands (NPWS 1994).
<i>Eastern Osprey (Pandion cristatus)</i>	V		Not associated to specific vegetation formation (NPWS 2002).
<i>Eastern Pygmy-possum (Cercartetus nanus)</i>	V		Rainforest, dry sclerophyll forest / woodland and heathland (OEH 2015).
<i>Grey-headed Flying-fox (Pteropus poliocephalus)</i>	V	V	Rainforests, wet, dry and swamp sclerophyll forests and woodlands (NSWSC 2001).
<i>Little Bentwing-bat (Miniopterus australis)</i>	V		Rainforest and dry sclerophyll forest (NPWS 2002b).
<i>Pale-vented Bush-hen (Amaurornis moluccana)</i>	V		Rainforests, wet, dry and swamp sclerophyll forests, grasslands, heathlands (NPWS 2002b).
<i>Spotted-tailed Quoll (Dasyurus maculatus)</i>	V	E	Rainforests, wet, dry and sclerophyll forests, grasslands.
<i>White-eared Monarch (Carterornis leucotis)</i>	V		Ecotone between rainforest and wet, dry and swamp sclerophyll forest (OEH 2015).
<i>Southern Myotis (Myotis macropus)</i>	V		Not associated to specific vegetation formation (OEH 2015).

4 Koalas and Fire

4.1 Overview

Bush fire has always played a role in the viability and persistence of koala populations, and their eucalypt forest habitats are among the most fire-prone ecosystems on earth. Bush fires can be a threatening process, but this largely depends on scale and intensity. While large, high intensity canopy fires have the potential to eliminate koalas from extensive tracts of forest, fire is nonetheless essential for the maintenance of koala habitat, and long-term fire exclusion can lead to irreversible habitat decline and displacement.

The most significant fire management issues affecting the Tweed Coast koala include:

- Large, high intensity bush fires killing individual koalas
- Peat fires that cause widespread collapse of canopy trees
- Fire exclusion resulting in koala habitat decline and displacement

Other fire management issues with lesser relevance to the Tweed Coast koala include:

- High frequency fires
- Hazard reduction burning

4.2 High Intensity Bush fire

4.2.1.1 GENERAL

High-intensity canopy fires pose a serious threat to koalas, particularly in areas of fragmented habitat. Being a slow-moving arboreal animal, high intensity canopy fires can cause death or injury of koalas (Lunney *et al.* 2004). Koalas which survive the initial canopy fire may still succumb to starvation following widespread canopy scorch (Melzer *et al.* 2000), or dog attack and road mortality as animals move in search of unburnt habitat (Lunney *et al.* 2007).

Long-term impacts on koala populations are largely determined by the ability of the population to recover from the bush fire event, through either local population recovery and/or immigration from the broader metapopulation. 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 (Matthews *et al.* 2007). However, in fragmented habitat, local recovery and immigration may be limited and high intensity fires can be a significant driver of population decline. Extensive 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.

The impact of *multiple* fire events on koala populations is discussed in **section 4.5**.

4.2.1.2 TWEED COAST

According to the Habitat Study (Phillips *et al.* 2011), high intensity bush fires during 2004 and 2009 were the primary cause of:

- i. the recent decline in the koala population on the Tweed Coast, and
- ii. the presence of large areas of unoccupied but suitable habitat.

Since reliable records began in 1978, bush fire has affected approximately 1 618 ha (58%) of koala habitat in the study area (**Map 1**). Six major bush fires were greater than 100 ha and affected extensive areas of koala habitat (**Table 8**). While there is no direct evidence of koala mortality from these bush fires, some mortality is assumed likely, and the loss of any individuals from the declining Tweed Coast koala population is believed to be unsustainable in the long-term.

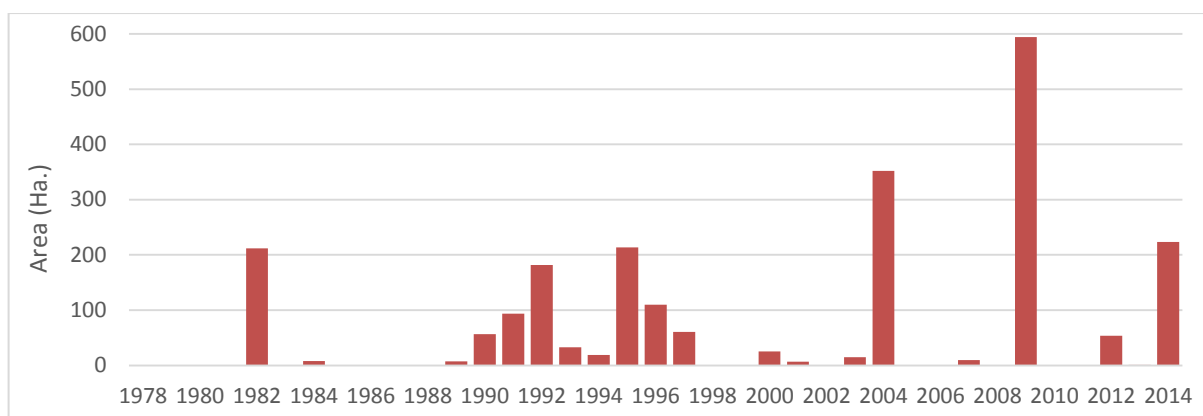


Figure 1. Extent of all bush fires affecting koala habitat since 1978.

Table 8. Large bush fires (>100 ha.) affecting koala habitat since 1978.

** Denotes fires specifically attributed to the decline of the Tweed Coast Koala population (Phillips et al. 2011).*

Year	Location	Affected Habitat
1982	North of Cudgen Lake	<ul style="list-style-type: none"> 212 ha including Swamp Mahogany, Paperbark and Swamp Box forest
1992	South of Wooyung	<ul style="list-style-type: none"> 163 ha including Paperbark, Swamp She-oak and Swamp Box forest
1995	West of Cudgen Lake	<ul style="list-style-type: none"> 150ha including Paperbark, Swamp Mahogany & Blackbutt forest
2004* (Oct)	West of Bogangar	<ul style="list-style-type: none"> 325 ha including Blackbutt and Paperbark forest Canopy scorch severe for approx. 60% of burn, and limited in the remainder Large areas of adjacent habitat unburnt
2009* (Dec)	West & north of Cudgen Lake	<ul style="list-style-type: none"> 580 ha Paperbark & Blackbutt forest complex. and over 200 ha of adjacent habitat Canopy scorch severe for approx. 70% of burn, and limited in the remainder
2014 (Dec)	Pottsville Wetland	<ul style="list-style-type: none"> 220 ha of Paperbark, Swamp Mahogany, and Swamp Box forest 95% of contiguous habitat affected Mostly limited to understorey with approx. 70% of canopy remaining unscorched

Importantly, koala mortality is likely to vary with fire intensity across bush fire areas. The *mapped* extent of these larger bush fires suggests that the vast majority of each contiguous habitat block was burnt, with little or no unburnt habitat to provide refuge for the persistence of koala individuals from affected local populations. However, analysis of post-fire imagery indicates variable burn intensity within mapped burn areas, including areas of limited or no apparent canopy scorch over large areas, including approx. 30% of the 2004 Bogangar fire extent, and c. 70% of the 2014 Pottsville fire extent (**Figure 2**). So while koala mortality associated with these large bush fires was potentially high, large areas of unburnt canopy are likely to have provided refuge and post-fire foraging resources for surviving individuals. Indeed, survey of the Pottsville Wetlands seven months after the 2014 fire found that koala activity had remained steady at all sites. Reports of breeding females in the locality have also been made to Council (TSC 2015b).

Large areas of koala habitat between Round Mountain and Koala Beach have remained unburnt since 1978.



Figure 2. Relative extent of canopy scorch for bush fires at Bogangar (2004) and Pottsville (2014; Tanya Fountain). For the Bogangar fire, the hashed area shows the mapped burn extent, while the background satellite image (Landsat 4 TM; 14/11/2004) shows areas of scorched canopy (black to pink areas) and healthy canopy (green areas), which generally correlate with south-facing slopes and gullies. In the Pottsville burn, scorched canopy (grey areas) generally coincided with low canopy above dense healthy vegetation.

4.3 Peat Fires

Low lying vegetation communities subject to seasonal inundation or waterlogging, such as Paperbark forests, 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 by bush fire or prescribed burning. Once ignited, peat fires can burn below the ground surface for weeks or months, causing re-ignitions and long-term damage to ecosystems. In severe cases, extensive soil subsidence and / or burning of tree roots can cause widespread tree collapse.

On the Tweed Coast, forested wetland communities that are indicative of peat soils comprise 1,435 ha (51.8%) of koala habitat. In 2009, a large bush fire in Paperbark forests to the west of Cudgen Lake resulted in peat fires burning for several weeks (David Cook, pers. comm. May 2015), and causing the widespread collapse of approximately 23 ha of Paperbark forest (**Figure 3**). The loss of this forest not only represents the loss of a substantial area of Preferred Koala Habitat, but more importantly, it has seriously compromised the main linkage between two of the largest koala metapopulation cells on the Tweed Coast (**Figure 4**). Before the fire, the Paperbark forest created an unbroken forested corridor of secondary koala habitat that was more than 700 m wide at its narrowest point. Tree collapse after the fire severely reduced connectivity to a discontinuous strip of Paperbark trees (c. 20-90 m wide) on the western lake shore, requiring migrating koalas to traverse open ground in several places. Localised areas of Paperback collapse have also resulted from the 2014 Pottsville fire, which occurred during a prolonged dry period (M. Hopkins pers. comm. October 2015).

Reducing the risk of peat fires primarily involves the avoidance of bush fire or prescribed burns during extended dry periods when the dry peat layer is vulnerable to ignition. Bush fires are more likely to occur during extended dry periods, greatly increasing in the likelihood of damaging of peat fires. Accordingly, hazard reduction burns undertaken when the peat layer is protected by an elevated water table are advised to reduce fuel loads for dry season bush fire.



Figure 3. Widespread collapse of koala habitat (Paperbark forest) caused by peat fire in December 2009 on the western shore of Cudgen Lake.

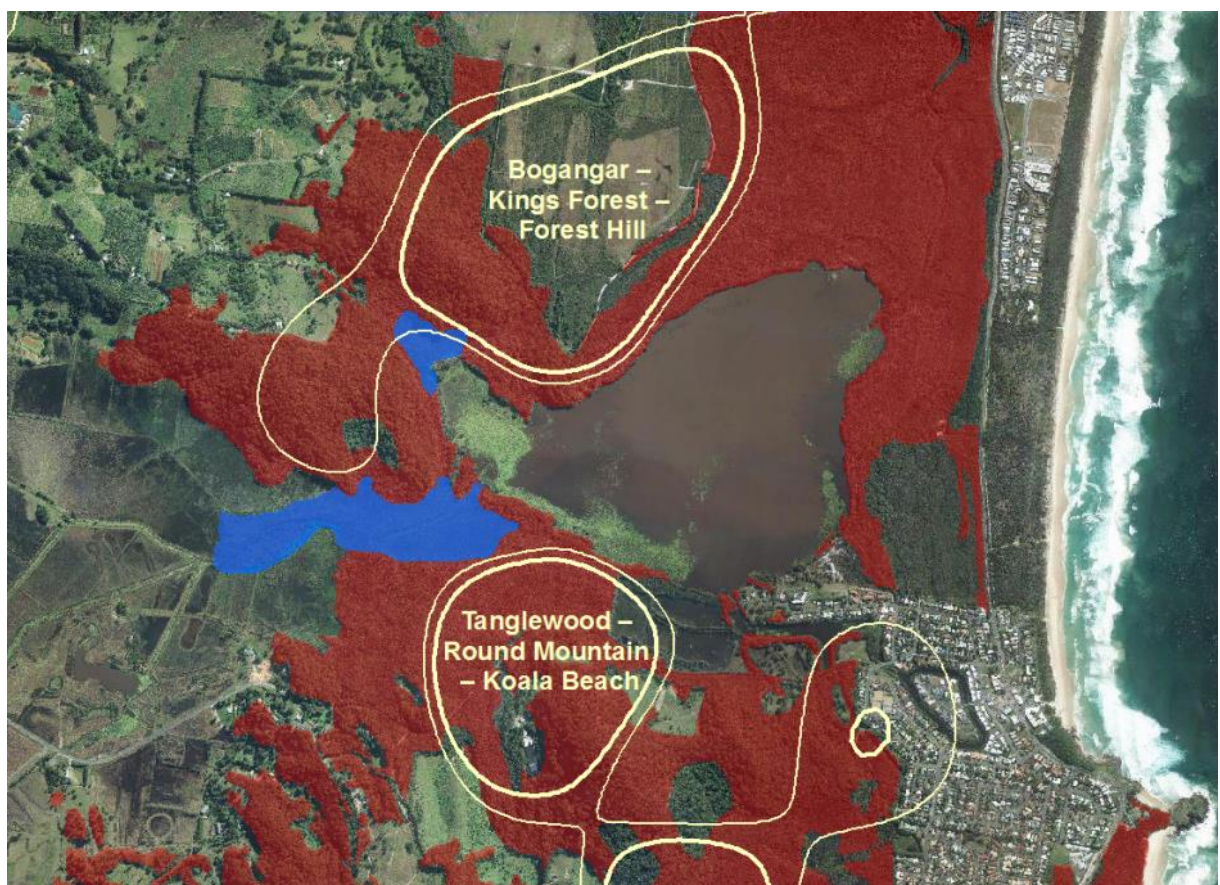


Figure 4. Collapse of koala habitat (blue) following 2009 peat fire has severely reduced connectivity between koala habitat areas (red) and two of the largest koala metapopulation cells (yellow lines) of the Tweed Coast.

4.4 Fire Exclusion (Low Frequency Fire)

4.4.1 Overview

Long-term fire exclusion is recognised to have several potentially severe consequences for koala conservation. Firstly, fires consume fuel, and the exclusion of fire is widely recognised to allow fuel accumulation, thereby increasing habitat flammability and maximising the likelihood of large, high intensity bush fires and high koala mortality. Conversely, on sites where fire exclusion allows rainforest expansion into the understorey, the developing rainforest strata can *reduce* community flammability through suppression of flammable understorey vegetation and accelerated litter decomposition. While reduced flammability may potentially reduce koala losses from bush fires, ongoing rainforest expansion could ultimately lead to the progressive decline and eventual displacement of koala habitat over large areas of the Tweed Coast.

The likelihood of these divergent consequences depends largely on the availability of surface and understorey layer fuels which fundamentally influence the ignitability and rate of spread of fires (Sullivan *et al.* 2012). With increasing time since fire, fuels in all layers continue to accumulate (**Figure 5**). However, a developing rainforest midstorey can suppress understorey fuel layers leading to reduced overall community flammability.

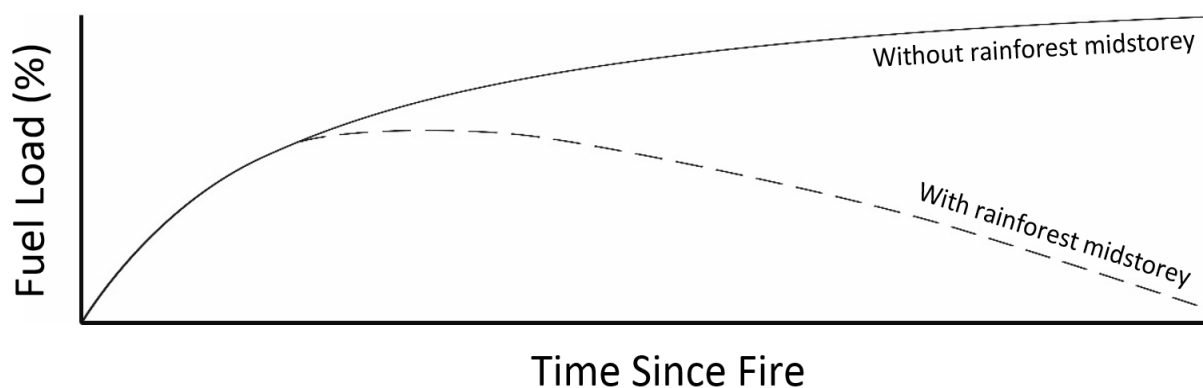


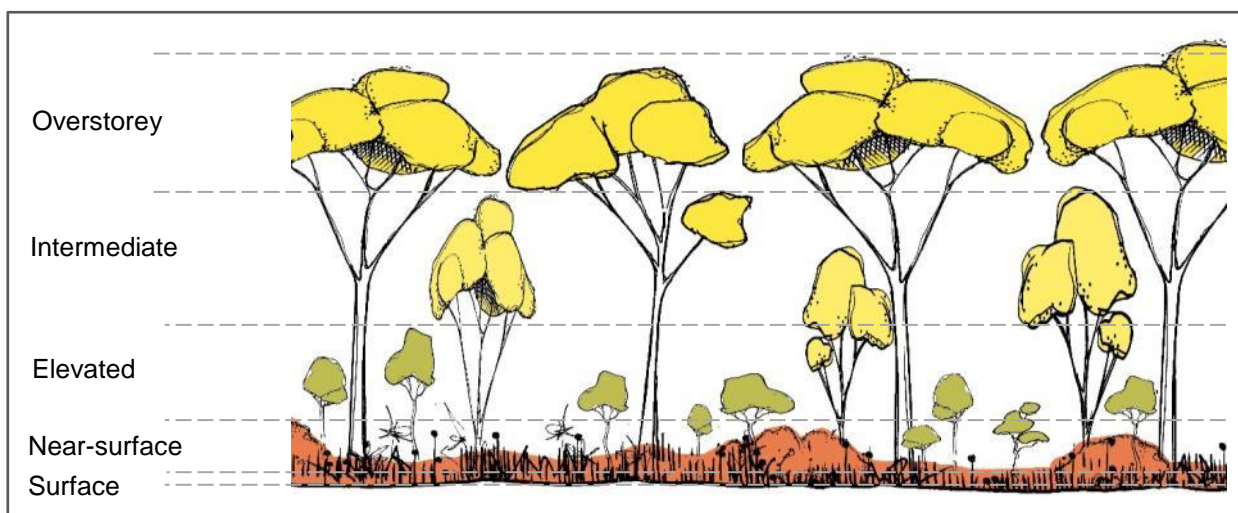
Figure 5. Surface and understorey layer fuel loads over time in vegetation with and without rainforest midstorey.

Finally, an intermediate fire exclusion pathway is possible, whereby areas of open forest avoid bush fires indefinitely, yet are also unable to support rainforest transition. While this may seem favorable to koala conservation, koala food trees require periodic fire for ongoing recruitment, and if fire does not facilitate recruitment within the lifespan of established plants or seed banks, local extinction will ensue.

4.4.2 Fuel Accumulation & Increased High Intensity Bush fires

Fire intensity and extent is largely governed by the volume and continuity of understorey vegetation (**Figure 6**), particularly surface fuels (i.e. leaf, twig & bark litter), near-surface fuels (i.e. grasses & low shrubs) and elevated fuels (i.e. tall shrubs). With increasing time since fire, these layers progressively accumulate fuel, increasing the likelihood of intense bush fires in fire-excluded vegetation. Fuel accumulation is most rapid in the decade after fire, although fuels in all layers can continue to increase for several decades (e.g. 22 years; Gould *et al.* 2007). By increasing the total fuel load, and allowing ongoing structural development of the fuel bed, fire exclusion increases the rate of spread, flame height and intensity of bush fires, as well as the number and distance of spot fires (Gould *et al.* 2007). The impact of high intensity bush fire on koalas are outlined in **section 4.2**.

Figure 6. Layers of fuel in forest vegetation (adapted from Gould *et al.* 2007).



This relationship of increasing flammability with time since fire underpins the practice of hazard reduction burning, which is the primary tool for reducing the risk of high intensity bush fires worldwide. Hazard reduction burns are discussed further in **section 4.5**.

4.4.3 Habitat Decline & Displacement by Rainforest

While fire exclusion typically increases sclerophyll forest flammability, rainforest expansion into the forest understorey interrupts this process, ultimately reducing flammability through suppression of flammable shrubs and grasses and accelerated litter decomposition (**Figure 5**). Continuing rainforest development and declining flammability trigger a cascade of positive feedback loops that can ultimately have irreversible impacts on koala habitat, including:

- suppressed recruitment of koala trees;
- premature decline of established food trees; and
- the ultimate displacement of koala habitat

RAINFOREST TRANSITION & DECREASING FLAMMABILITY

Rainforest expansion into fire-excluded open forests occurs worldwide (Bond *et al.* 2005) and is widely reported for high-rainfall regions throughout Australia (e.g. Gilbert 1959; Stanton *et al.* 2014). A general model of rainforest expansion recognises that rainforest trees often recruit into the understorey of open forests in the interval between fires, but are removed by fires that return before they have developed the ability to survive fire (Ashton & Attiwill 1994; Bowman 2000; Murphy & Bowman 2012). With continuing fire exclusion, the developing rainforest midstorey shades out flammable ground layer vegetation, thereby inhibiting further fires and enabling continued rainforest development (Williams 2000; Hoffmann *et al.* 2012).

The likelihood of a closed forest canopy forming and displacing the flammable understorey is a function of both fire frequency and tree growth rates. Any factor that promotes tree growth rates, such as increased water, nutrient or carbon dioxide availability, will increase the likelihood of rainforest trees recruiting, maturing and forming a closed stratum in the interval between fires. So too will any factor that increases the fire interval, such as topographic fire protection, suppression of bush fires or reduced anthropological burning (Murphy & Bowman 2012). Implicit in the model is the concept that if resources on a site are sufficient to support transition, then fire interval is the primary

determinant of whether or not transition will occur.

With increasing time since fire, efforts to restore these sites may be complicated by encroaching rainforest trees that are no longer removed by reintroduction of fire alone, and the difficulties of reintroducing fire where flammable understoreys have been shaded out.

SUPPRESSED RECRUITMENT OF KOALA FOOD TREES

Many plant species within fire-dependent vegetation are dependent on fire for recruitment and can be driven to local extinction by fire exclusion. The reproduction and recruitment of many plant species is cued to coincide with the increased availability of resources, and the reduced competition within gaps of the post-fire environment (Whelan 2002). Gap-phase recruitment is a characteristic of most koala food trees (e.g. *Eucalyptus*, *Melaleuca* and *Lophostemon* spp.), and understorey removal and sun exposure of the bared soil in large gaps following fire is generally a prerequisite for the successful establishment of canopy replacing cohorts (Turton & Duff 1992; Ashton & Attiwill 1994).

Developing rainforest midstoreys are likely to further inhibit recruitment of koala food trees, by shading and reducing the likelihood of fire events necessary for their recruitment. However, even with a fire event, most rainforest species can survive complete top kill by intense bush fire (Campbell & Clarke 2006), and rapid regeneration of the rainforest midstorey after fire may directly compete with recruiting overstorey sclerophyll species, and may lead to suppressed or failed recruitment on sites with advanced rainforest midstorey development.

ACCELERATED DECLINE OF ESTABLISHED KOALA FOOD TREES

Long-term fire exclusion can cause profound changes in dry and moist eucalypt forest soils which negatively impact on tree health, including altered pH, nitrogen availability and alteration of mycorrhizal and other microbial communities (Jurskis 2005; Turner *et al.* 2008).

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 (e.g. Ellis, 1985; Werkman *et al.*, 2008). Rainforest development typically modifies the soil physical and chemical environment, altering the competitive relationships between the midstorey and sclerophyll overstorey. The mechanisms accelerating crown decline include increased competition for soil water availability during droughts (Kirkpatrick & Marks 1985; Close *et al.* 2009) and locking up essential phosphorous and/or cations in rainforest litter and midstorey biomass (Close *et al.* 2009).

POTENTIAL FOR RAINFOREST TRANSITION ON THE TWEED COAST

While no research has assessed rainforest transition in the study area, high rainfall and widespread distribution of suitable soils and rainforest seed-source areas suggest that rainforest transition may be possible throughout many areas of fire-excluded koala habitat on the Tweed Coast. The potential for change in the region is indicated by recent vegetation mapping across the neighbouring Byron Shire, where since the 1990s, 35% of wet sclerophyll forest has transitioned to rainforest, and c. 90% of dry sclerophyll forest understorey is now typified by an emerging layer of rainforest trees (BSC 2016).

Like Byron Shire, the study area's annual rainfall of >2000mm coincides with a rainfall threshold identified for far north Queensland, above which transition of coastal open forests to rainforest is ubiquitous after prolonged fire exclusion (Russell-Smith *et al.* 2004; Stanton *et al.* 2014).

Secondly, all major soil types on the Tweed-Byron coast support rainforest in a range of topographic positions, including on exposed headlands, escarpments and elevated sand dunes (TSC 2004). Furthermore, mixed regrowth co-dominated by rainforest trees and exotic mesophyll trees such as Camphor Laurel (*Cinnamomum camphora*), Umbrella Trees (*Schefflera actinophylla*) and Privets (*Ligustrum* spp.), is widespread on formerly supporting open forest (TSC 2004), while examples of advanced rainforest midstorey development are common on richer sites such as at Duranbah and Tanglewood (A. Baker pers. obs.).

Finally, long-distance dispersal (>1 km) of rainforest seeds by frugivorous birds and bats is well documented on the far north coast of NSW (e.g. Date *et al.* 1996). Nearly 90% of all koala habitat on the Tweed Coast is located within 1500 meters of mapped rainforest vegetation (TSC 2004), and the diversity and abundance of frugivorous birds and bats in the study area is one of the highest in NSW (Milledge 1991).

4.5 High Frequency Fire & Hazard Reduction Burns

The threat of high intensity bush fires is exacerbated when bush fires frequently return to the same area of habitat. The continuing decline of koala habitat populations is expected wherever recurrent bush fires remove a proportion of the breeding population at a rate faster than the time required for the loss to be replaced by successive koala generations and inflow from the wider metapopulation (Phillips *et al.* 2011). *High frequency fire* is also listed as a key threatening process under the TSC Act, and is specifically identified as having the potential to suppress regeneration of preferred food trees in the NSW *Recovery Plan for the koala* (DECC 2008).

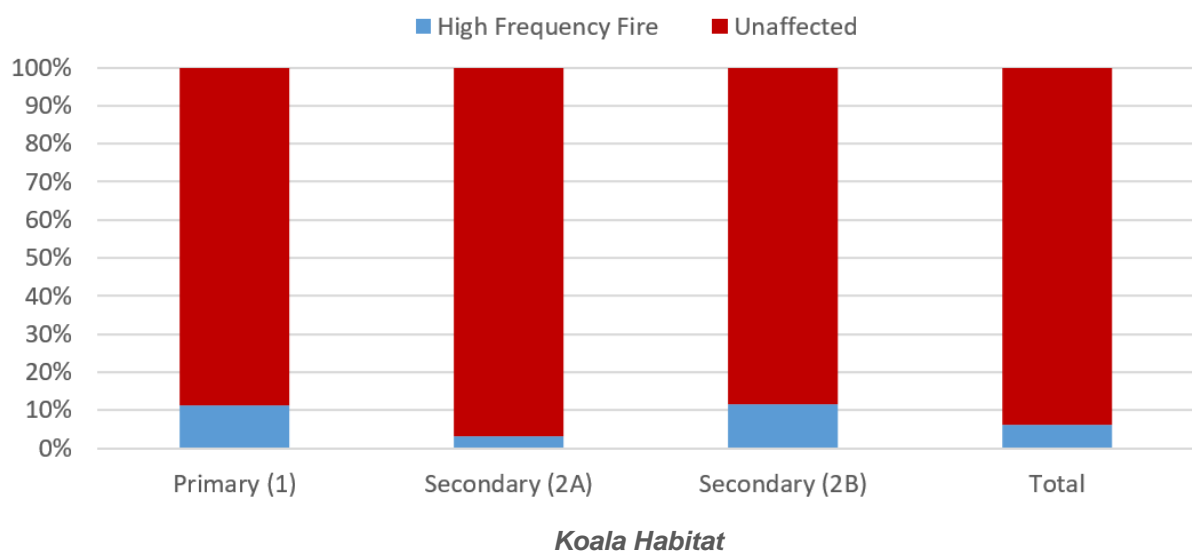
On the Tweed Coast, the Habitat Study identified *high frequency* fires as a major contributor to recent decline of the Tweed Coast koala populations. While high fire frequency likely contributes to the attrition of local koala populations, fire history analysis reveals that high frequency fire is relatively limited in koala habitat on the Tweed Coast, and is likely to be a relatively minor factor compared to bush fire intensity and extent.

Fire history analysis revealed that only 173.6 ha. (6.3%) of koala habitat has been affected by *high frequency fire* since 1978, based on a fire interval of 6 years or 1 koala generation (after Phillips *et al.* 2011; **Figure 7**). Furthermore, satellite imagery analysis showed that many areas affected by high frequency fire showed limited evidence of canopy scorch in one or both fires, reducing the likelihood of compounding impacts on koala mortality or temporary foraging resources.

High frequency hazard reduction burns are identified as a potential threat to Tweed Coast koala populations (Phillips *et al.* 2011). Importantly however, analysis of fire records shows that the extent of hazard reduction burning has been extremely limited on the Tweed Coast since at least 1978. During this period HR burns have only affected 2.6 ha (0.1%) of all koala habitat, no prescribed fires correlated to areas identified as being affected by high frequency fire, and there are no records of HR burns within the koala metapopulation cells of Phillips *et al.* (2011).

In summary, neither high frequency fire or hazard reduction burns are a significant threat to the Tweed Coast koala. Conversely, the major fire-related threats identified previously (i.e. high intensity fire, peat fires, and long-term habitat decline) result from *low-frequency fire* and fire exclusion, and their management requires a major increase in the use of hazard reduction burning across the study area.

Figure 7. Proportion of koala habitat affected by high frequency fire since 1978. Minimum fire interval is 6 years or 1 koala generation (after Phillips *et al.* 2011).



5 Current Fire Risk & Conditions

5.1 Bush Fire Season

The bush fire season for coastal areas of South East Queensland & the NSW far north coast generally extends between August & November (QPWS 2013, FNCBFMC 2009; **Figure 8**) and is characterised by frequent north to north-westerly winds, typically low rainfall, low humidity and increasing temperatures.

The bush fire season is associated with an increase in the number of days when the fire danger rating is 'very high' or above (i.e. forest/grass fire danger indices ≥ 25). Such conditions occur in the region when low pressure systems over southern Australia bring hot, dry, north-westerly winds. Summer typically brings higher humidity and increased rainfall to moist south-easterly winds and the commencement of the wet-season rains.

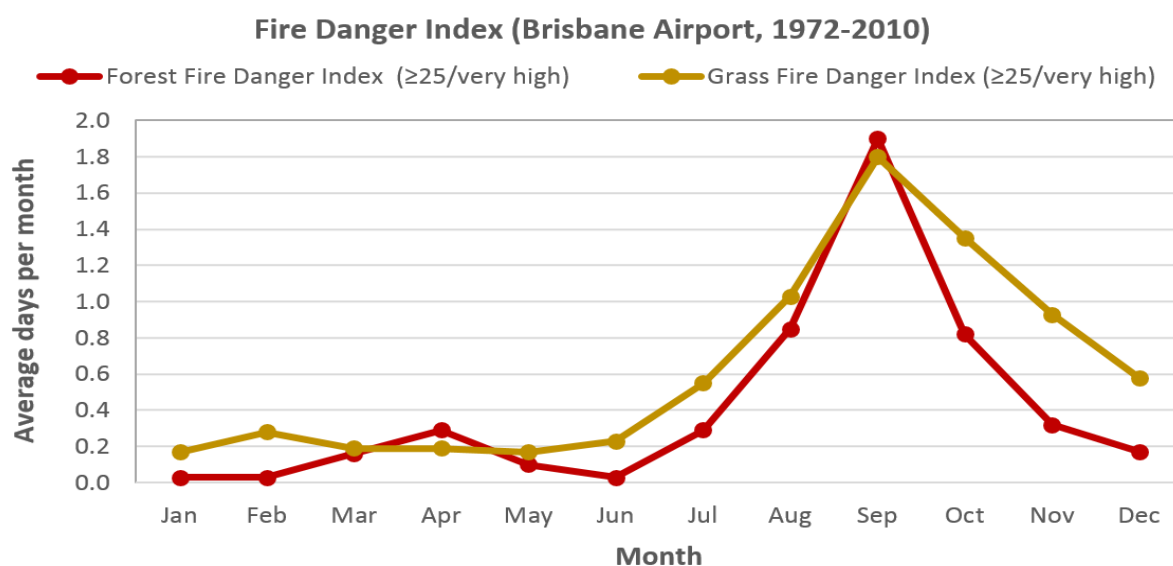


Figure 8. Fire weather risk in coastal SEQ and NE NSW (adapted from QPWS 2013).

5.2 Current Bush Fire Risk

A bush fire risk assessment was developed to determine hazard reduction priorities in the study area. The overall bush fire risk to koalas was determined by GIS analysis of the fuel hazard and peat fire risk across all areas of koala habitat. The methods of the assessment are outlined in **Appendix A**.

The current bush fire risk across all koala habitat in the study area is shown in **Figure 9** and **Map 5** (as hazard reduction priority). Importantly, over 57% of koala habitat is currently at high to very high bush fire risk.

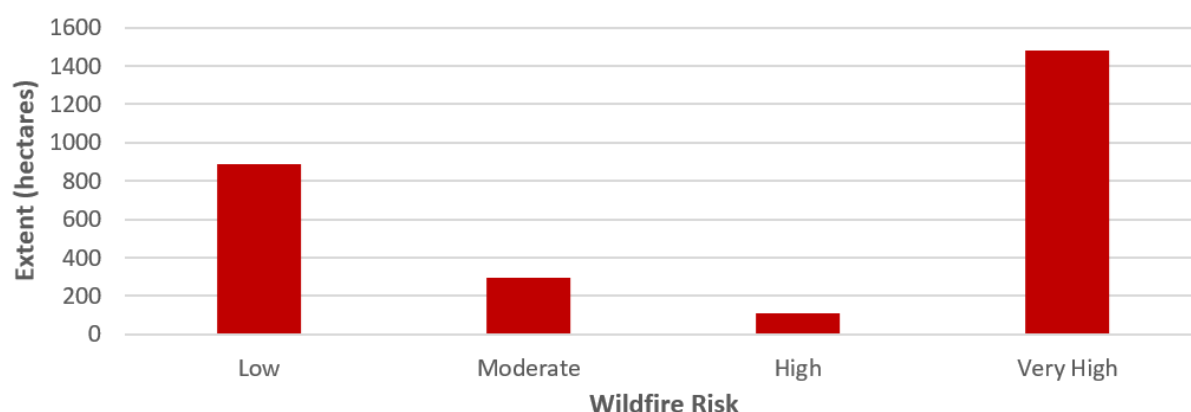


Figure 9. Current bush fire risk across all koala habitat.

5.3 Fire Interval Status

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

On the Tweed Coast approximately 1,241 ha (45%) of koala habitat is currently beyond recommended burn intervals (i.e. overdue for fire;

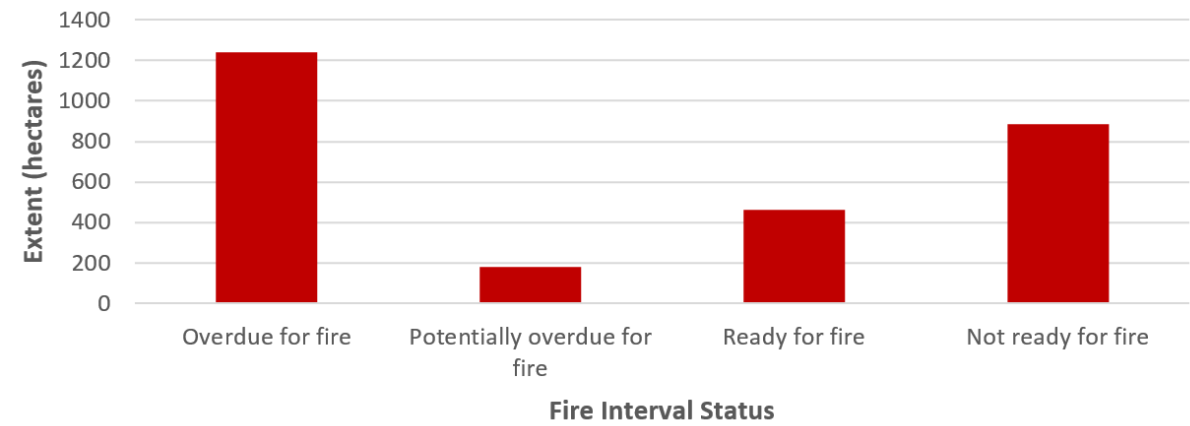


Figure 10; Map 4). A well designed and implemented hazard reduction burn program is required to minimise the risk of either of these severe consequences eventuating.

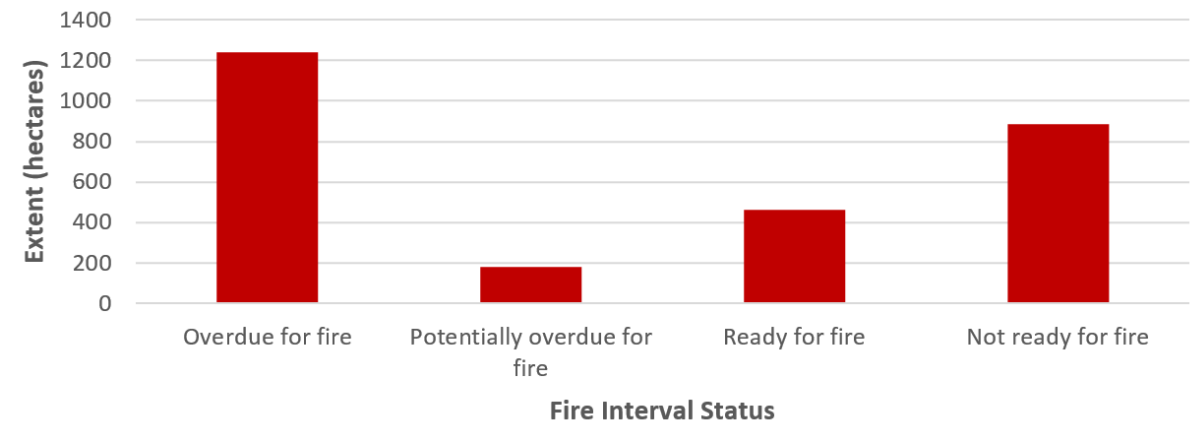



Figure 10. Fire interval status across all koala habitat within the southern KMA.

TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 1

Location & Context




Plan Area

 Koala Management Area
(Southern Tweed Coast)

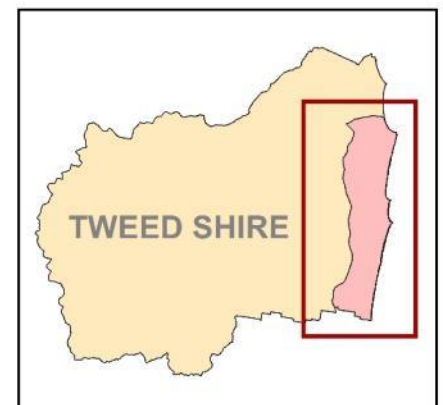
Koala Habitat

 Primary
 Secondary (Class A)
 Secondary (Class B)

Koala Metapopulations
(Phillips et al. 2011)

 High activity
 Significant activity
 Undefined boundary

 Kilometers
0 1 2 3 4



Map Extent



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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 2A

Other Conservation Values

Fire-dependent Values

 Threatened Species

 EECs & SEPP 14

(Freshwater Wetlands, Swamp Oak, Swamp Sclerophyll Forest, Subtropical Coastal Floodplain Forest, Coastal Cypress & SEPP 14 Wetlands)


Fire-sensitive Values

 Threatened Species

 EECs & SEPP 26

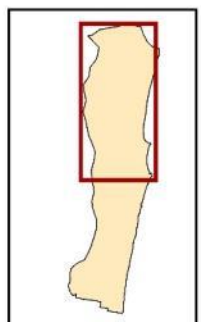
(Rainforest, Saltmarsh & SEPP 26 Littoral Rainforest)

Fire-neutral Values

 Threatened Species

Koala Values

 Koala Habitat



Map Extent

0 0.5 1 1.5 2 Kilometers

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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 2B

Other Conservation Values

Fire-dependent Values

 Threatened Species

 EECs & SEPP 14

(Freshwater Wetlands, Swamp Oak, Swamp Sclerophyll Forest, Subtropical Coastal Floodplain Forest, Coastal Cypress & SEPP 14 Wetlands)

Fire-sensitive Values

 Threatened Species


 EECs & SEPP 26

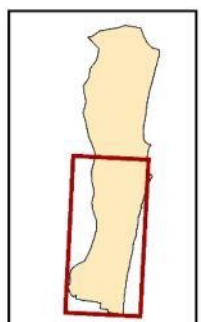
(Rainforest, Saltmarsh & SEPP 26 Littoral Rainforest)

Fire-neutral Values

 Threatened Species

Koala Values

 Koala Habitat



Map Extent

0 0.5 1 1.5 2 Kilometers

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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 3A

Fire History

Koala Habitat Fire History (1978-2015)

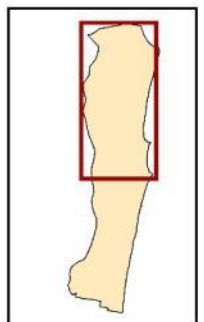
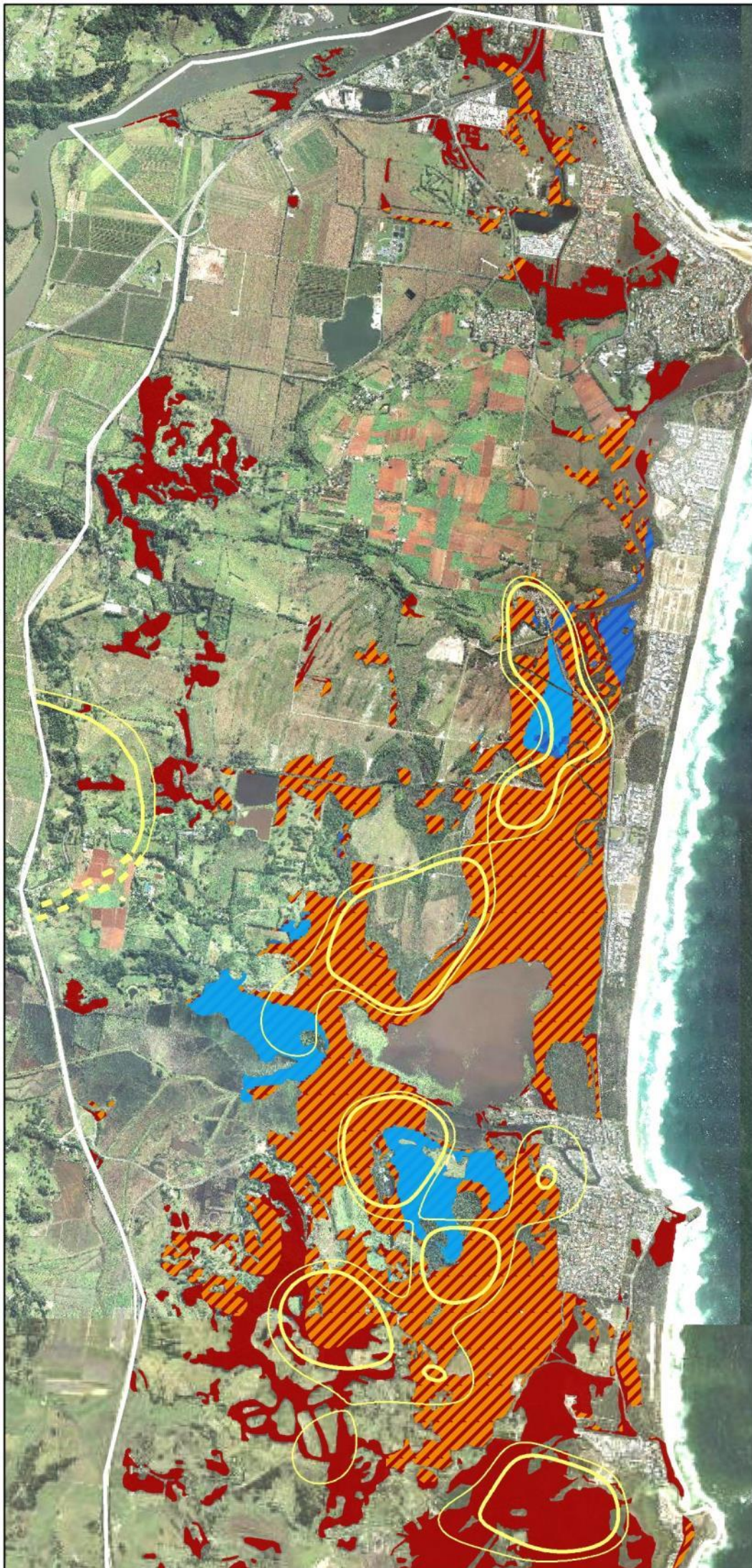
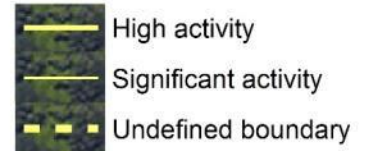


High Frequency Fire

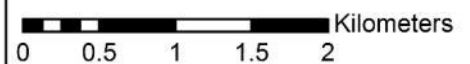


Koala Metapopulations

(Phillips et al. 2011)



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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 3B

Fire History

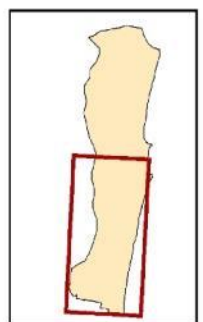
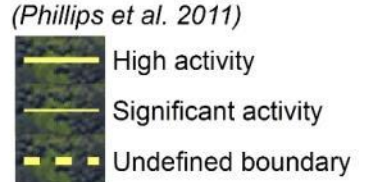
Koala Habitat Fire History (1978-2015)



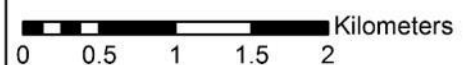
High Frequency Fire



Koala Metapopulations (Phillips et al. 2011)



Map Extent



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
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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 4A

Fire Interval Status


Beyond Threshold

-  Overdue for fire now
-  Potentially overdue for fire

Within Threshold




-  Ready for fire

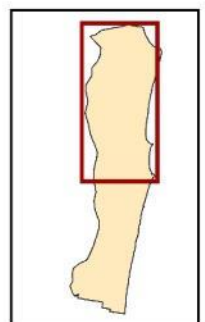
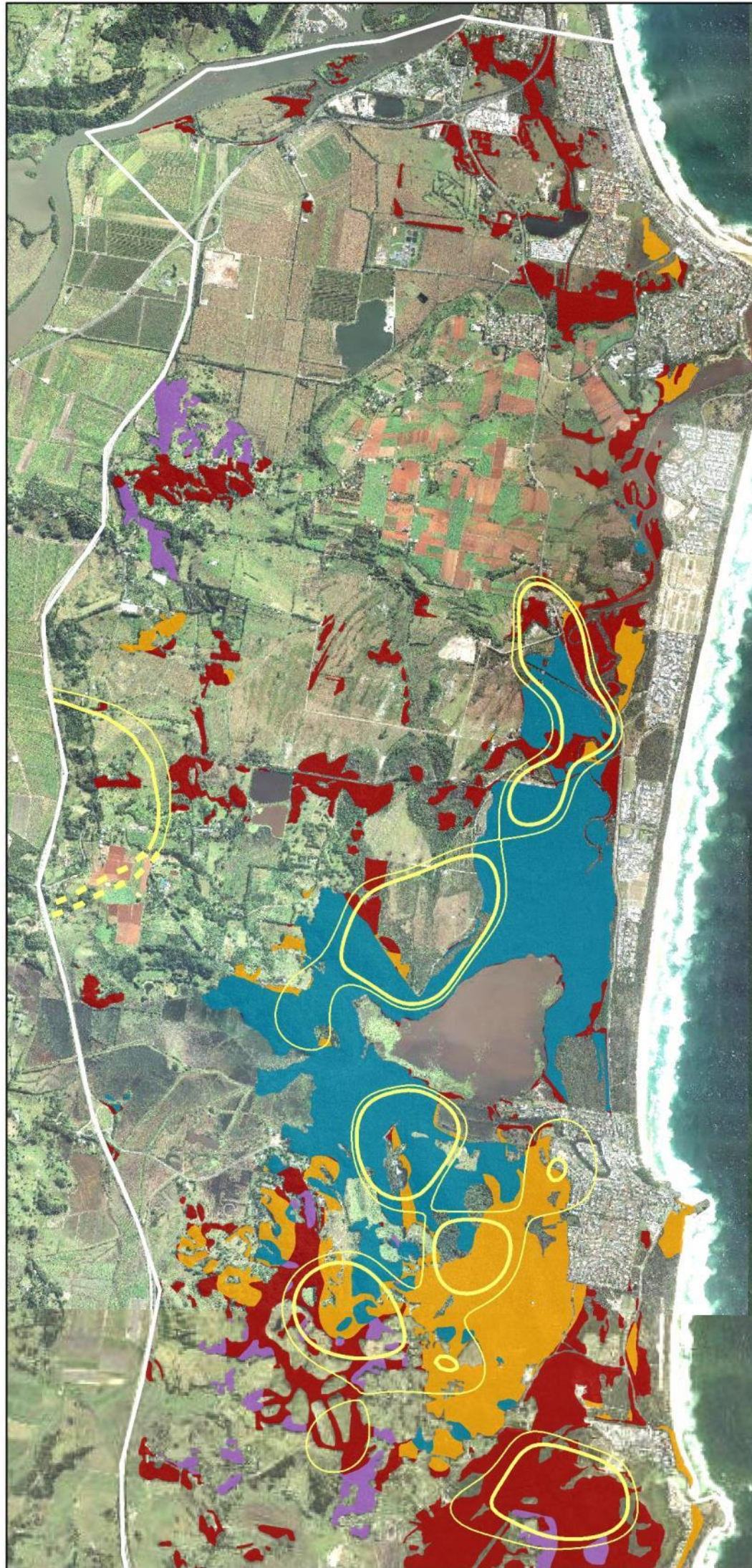
Below Threshold

-  Not ready for fire

Koala Metapopulations

(Phillips et al. 2011)

-  High activity
-  Significant activity
-  Undefined boundary



Map Extent

0 0.5 1 1.5 2 Kilometers

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

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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 4B

Fire Interval Status


Beyond Threshold

-  Overdue for fire now
-  Potentially overdue for fire

Within Threshold




-  Ready for fire

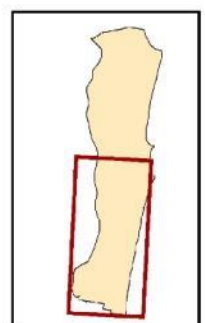
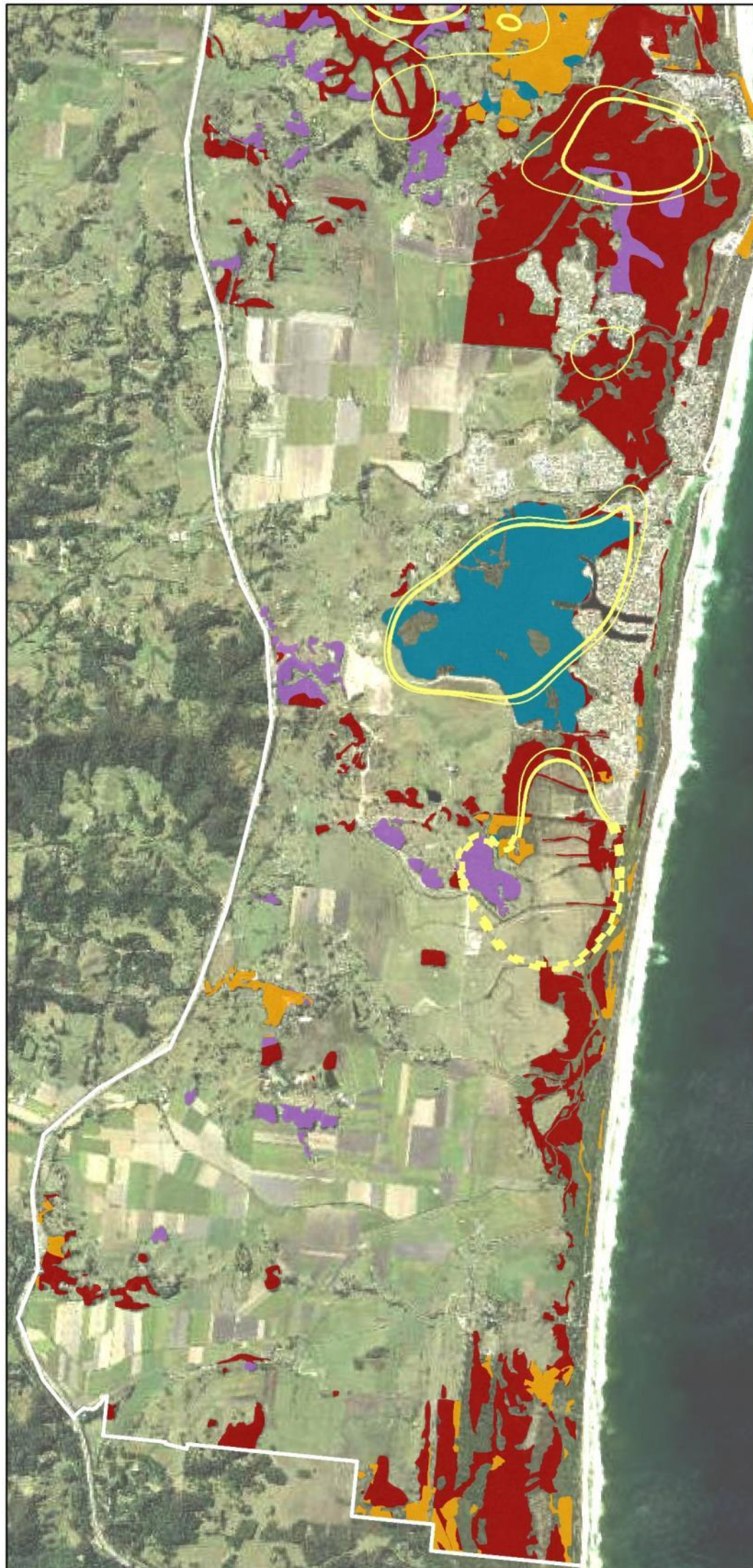
Below Threshold

-  Not ready for fire

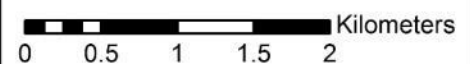
Koala Metapopulations

(Phillips et al. 2011)

-  High activity
-  Significant activity
-  Undefined boundary



Map Extent



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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 5A

Hazard Reduction Priority Map

Fire Management




Apply Fire

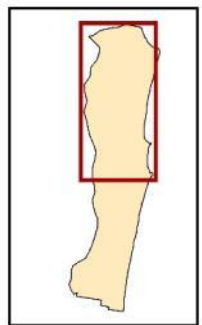
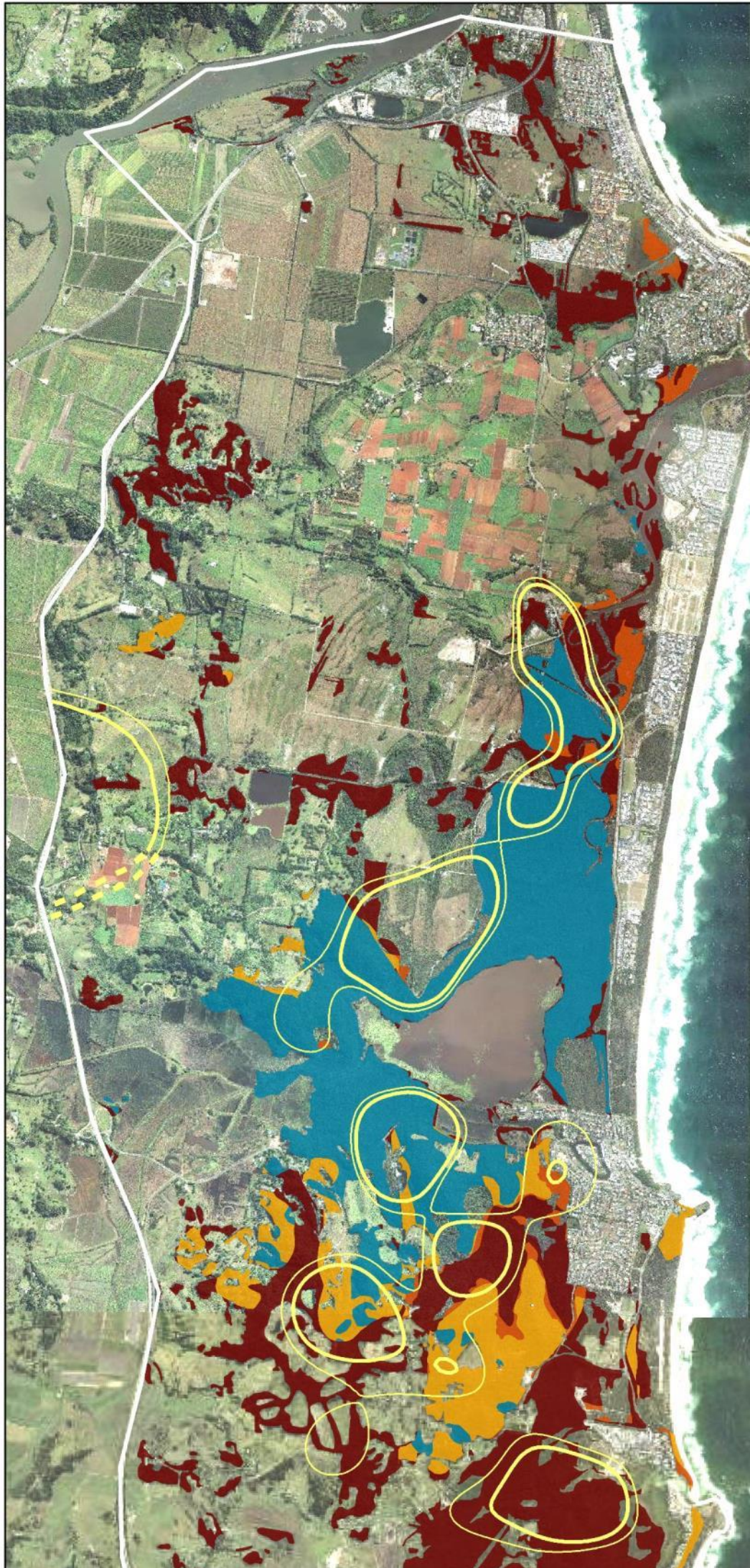
-  Low priority
-  Moderate priority
-  High priority

Exclude Fire

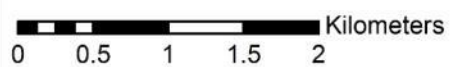
-  Exclude Fire

Koala Metapopulations (Phillips et al. 2011)

-  High activity
-  Significant activity
-  Undefined boundary



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TWEED COAST KOALA FIRE MANAGEMENT PLAN

Map 5B

Hazard Reduction Priority Map

Fire Management

Apply Fire




-  Low priority
-  Moderate priority
-  High priority

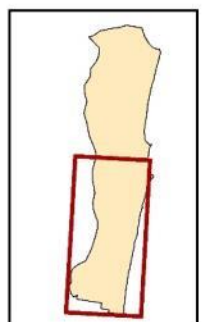
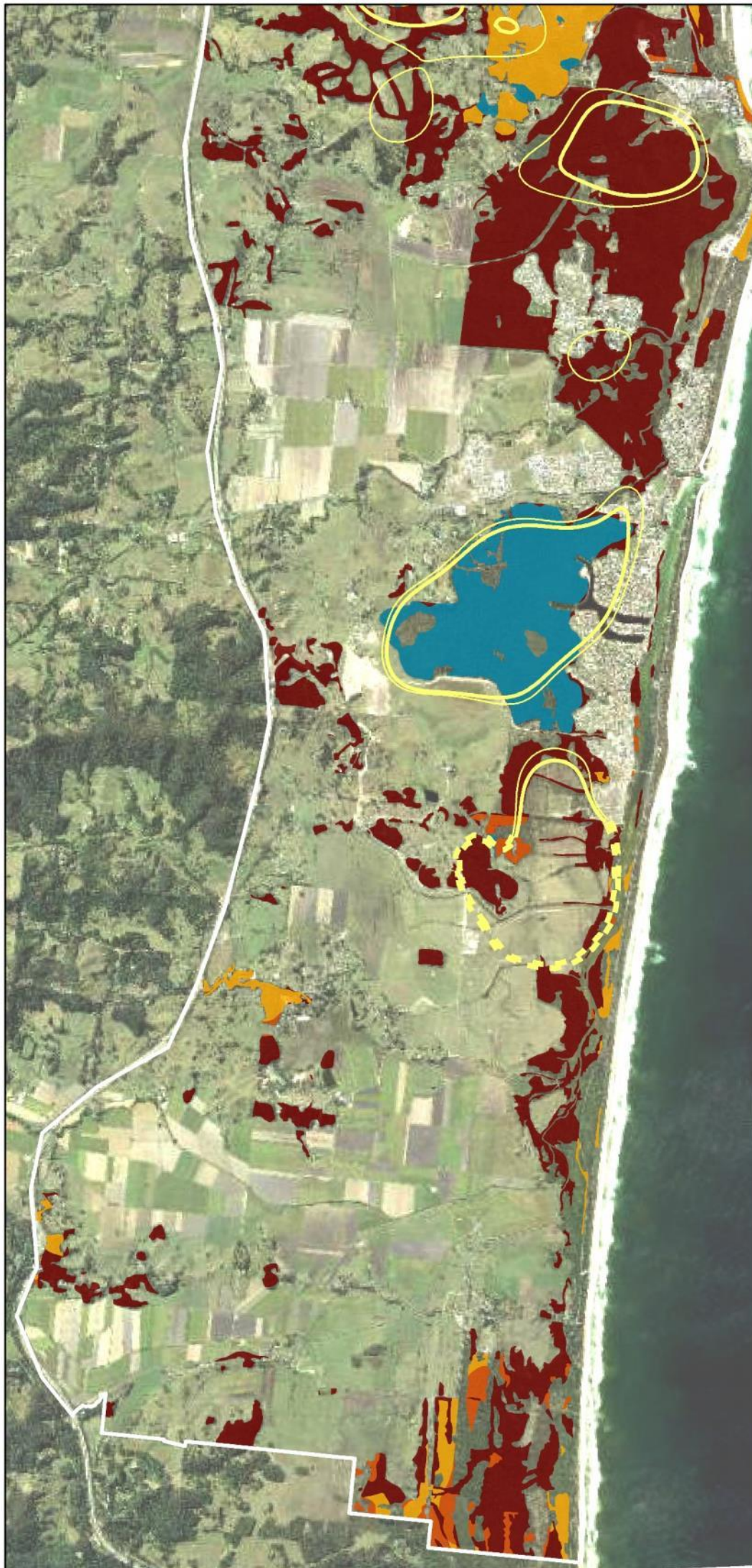
Exclude Fire

-  Exclude Fire

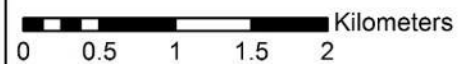
Koala Metapopulations

(Phillips et al. 2011)

-  High activity
-  Significant activity
-  Undefined boundary



Map Extent



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A photograph of a forest fire with a large white 'C' logo overlaid. The fire is burning in the foreground and middle ground, with smoke rising from the trees. The background shows a dense forest of tall trees. The logo is a large, white, stylized 'C' shape, positioned in the upper left quadrant of the image.

Management Strategies

Overview

The management of the identified fire management issues for the conservation of the Tweed Coast koala is outlined in the following four strategy areas:

1. ACCESS AND STRATEGIC FIREBREAKS
2. HAZARD REDUCTION
3. BUSH FIRE RESPONSE
4. EDUCATION, MONITORING & RESEARCH

Each strategy is outlined in the following manner:

BACKGROUND INFORMATION - Information which needs to be known in order to comprehend the subject and which provides a context for the outcomes, guidelines and actions.

DESIRED OUTCOMES - The desired condition of one or more specific attributes of the subject to be achieved by or before 2025.

EXISTING SITUATION - The current condition of the attributes referred to in 'Desired Outcomes'.

GUIDELINES AND POLICIES - Guidelines and policies to guide the change from the existing situation to the desired outcome.

ACTIONS - Actions needed to bring about the proposed change from the existing situation to the desired outcome.

ACCESS AND STRATEGIC FIREBREAKS

BACKGROUND INFORMATION

Fire trails provide access and strategic firebreaks for fire-suppression crews to attempt early containment of bush fires within larger vegetation blocks, and before they escalate into major fires that would incur significant suppression costs and potentially significant damage to community and environmental assets. However, fire trails are also important for the containment of hazard reduction burns, dividing larger vegetation blocks into smaller compartments, thereby allowing large areas to be safely and progressively burnt in stages.

Fire trails provide access into areas of fire-prone vegetation to allow for both suppression of bush fire and the implementation of hazard reduction burns. An adequate access network for fire fighting vehicles is essential for the protection of koalas and their habitat.

While some access ways are specifically constructed and maintained as fire trails, all forms of access on both public and private tenure may potentially be of use for fire management. These include trails constructed for purposes such as public roads and thoroughfares, recreational/tourism activities, land management, as well as access to private property. All of these access ways should be identified and recognised as part of the total fire access network, even though they are not necessarily fire trails.

A number of additional fire trails around the Cudgen Lake area have recently been recommended for adoption by the FNCBFMC to protect both human life and property as well as koalas. These trails consist primarily of existing track networks on private land and within road reserves. Opportunities for additional access require urgent assessment in other areas of koala habitat, including Round Mountain and Pottsville.

Notwithstanding their value in fire suppression, fire trails may have adverse impacts on environmental values. Accordingly, where the establishment or upgrading of fire trails is proposed, this must be subject to impact assessment. While unauthorised access issues may be addressed by the installation of locked gates on some fire trails, the potential environmental management implications of additional trails may require consideration of alternative strategies for fire management.

One such alternative includes the use of "Wet" strategic lines to help restrict fire movement, where fire trails are otherwise impractical. This type of SFAZ would include a metal (or buried PVC) water line with metal risers and sprinklers which would be linked to either a reticulation network or that could be pressurised by fire-fighting vehicles during a fire event. Further opportunities for new SFAZ locations, such as static water supplies that can be used for firefighting purposes (e.g. dams, creeks, drainage channels or swimming pools) is required.

To ensure effective planning and implementation of fire management activities, knowledge of the location, condition and vehicle carrying capacity of fire trails is essential. To meet this objective the BFCC Fire Trails Policy (BFCC 2007) provides that all fire trails must be consistently classified, mapped and signposted on the basis of strategic importance and vehicle carrying capacity.

AIMS

By or before 2026, to have a comprehensive network of fire trails and strategic fire breaks established in and adjacent to core koala habitat areas.

EXISTING SITUATION

Development of the existing fire trail network has not paid specific consideration to koala conservation.

Large areas of koala habitat have no internal fire trails or strategic firebreaks allowing access for fire management activities, including the Pottsville Wetlands and the northern section of Cudgen Nature Reserve.

Existing tracks in and adjacent to koala habitat (including on private property) and not currently identified as fire trails could be potentially incorporated into the fire trail network.

Many fire trails in the network occur on private lands, and many private land owners will require education, encouragement and assistance with regular maintenance.

Existing static water supplies provide potential opportunities to fire management in koala habitat.

GUIDELINES & SAFEGUARDS

The construction, maintenance, classification, map depiction, and signage related to all fire trails is to be consistent with Fire Trails Policy of the Bush Fire Coordinating Committee (Policy No. 2/2007). The installation of signage consistent with this policy must avoid encouraging unauthorised access to private property or other access-restricted areas.

The establishment or upgrading of any fire trails must be subject to appropriate environmental impact assessment.

The FNCBFMC should work together to ensure that all fire trails are inspected annually. This should be a cooperative effort.

All new fire trails are to be included in the Far North Coast BFMC Fire Trail Register.

It is preferable for habitat areas to be bordered by well-defined and accessible vehicle tracks on all sides, but in particular the edge along which most bush fire suppression activities are likely to be required.

ACTIONS

Ensure all existing fire trails are consistent with the BFCC Fire Trails Policy (2/2007 – Annex D) in terms of i) classification, ii) construction, iii) maintenance, iv) map depiction and v) signage.

Locked gates are to be installed on existing fire trails where appropriate to prevent access for arson, dumping and recreational vehicle use.

Investigate and implement the establishment of additional fire trails and strategic fire breaks across all tenures utilising existing or disused trails and available static water supplies.

Investigate north south or east west trail to provide containment options and to minimise impact on Pottsville SEPP 14 wetland. Utilise existing trails, as per BFRMP (Treatment no 86; Asset No. 28;88 – Pottsville Wetlands)

Supply feedback to NPWS in relation to water pipelines and levees within Cudgen NR which may have been installed by Council and which may provide suitable SFAZ locations.

Opportunities for assisting private land owners to maintain fire trails on their lands are to be investigated.

Produce and distribute education materials for private landowners with fire trails on their properties:

- outlining the value of the fire management activities for koala and biodiversity conservation, and overall fire safety; and*
- encouraging landowners to maintain access and static water supplies on their properties.*

Create and implement an arson prevention program, including the use of fire trail gates, fencing, patrols, education, or signage as appropriate.

HAZARD REDUCTION

BACKGROUND INFORMATION

Hazard reduction works create areas of reduced fuel in order to reduce bush fire severity and assist fire suppression activities. Prescribed burning is the primary method of hazard reduction within bushland areas. Along the interface separating bushland and fire-sensitive assets (e.g. residential areas), hazard reduction typically involves mechanical clearing, mowing, and under-scrubbing.

Hazard Reduction Burning

Hazard reduction (HR) burning is the primary tool for reducing the risk of high intensity bush fire worldwide, and provides an invaluable tool for reducing the likelihood of high intensity bush fire and peat fires within koala habitat. The overriding premise of HR burning 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, HR burning reduces the rate of spread, flame height and intensity of bush fires, as well as the number and distance of spot fires (Gould *et al.* 2007). Strategic HR burning can be used to maintain a mosaic of low to moderate fuel levels across the landscape, increasing refugia for koalas during bush fires, while also facilitating improved bush fire suppression.

HR 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, an HR burn may be used to reduce fuels above peat soils when they are protected by a high water table, thereby minimising peat fire risk in subsequent fire seasons.

Finally, fire is also a crucial ecological process in koala habitat, and HR burns could play an important role in maintaining koala habitat condition by ensuring recruitment of koala food trees, and preventing wholesale displacement of koala habitat by rainforest. (See **section 4.4.3**)

Within koala habitat, well-planned and implemented HR burning provides an essential tool to:

- reduce koala mortality by reducing the intensity, extent and frequency of bush fire;
- reduce the likelihood of destructive peat fires;
- ensure ongoing recruitment of koala food trees;
- maintain an appropriate soil chemistry and microbiota for koala food trees; and
- prevent habitat displacement by rainforest transition.

Hazard Reduction Burns in Occupied Koala Habitat

The KPOM specifies that beyond the current 'koala generation' (until 2017) that bush fire is excluded from occupied habitat and a preference for manual, mechanical fuel reduction within occupied habitat to minimise risk from bush fire. (Section 10.3). However, while these prescriptions seek to avoid *all* risk to koalas from HR burns, mechanical hazard reduction at the landscape scale required (>870 ha.) is unrealistic on both financial and environmental grounds, and would therefore ultimately fail to address the overriding threat of bush fire mortalities to the Tweed Coast koala.

Accordingly, this Plan recommends that **hazard reduction burning is the primary strategy for hazard reduction in occupied koala habitat** on the grounds that hazard reduction burning:

- presents a low risk to koalas when conducted in accordance with specific guidelines; and
- provides the only method of hazard reduction that can realistically reduce koala mortality from bush fire under existing ecological and financial constraints.

The existing approach to bush fire management in the study area is largely reactive and limited to suppression of bush fires as they occur. This Plan recommends a proactive approach of hazard reduction burning to both reduce bush fire risk and maintain the ecological process of fire on which koala habitat depends. A comparison of reactive and proactive approaches to bush fire in koala habitat is given in **Figure 11**.

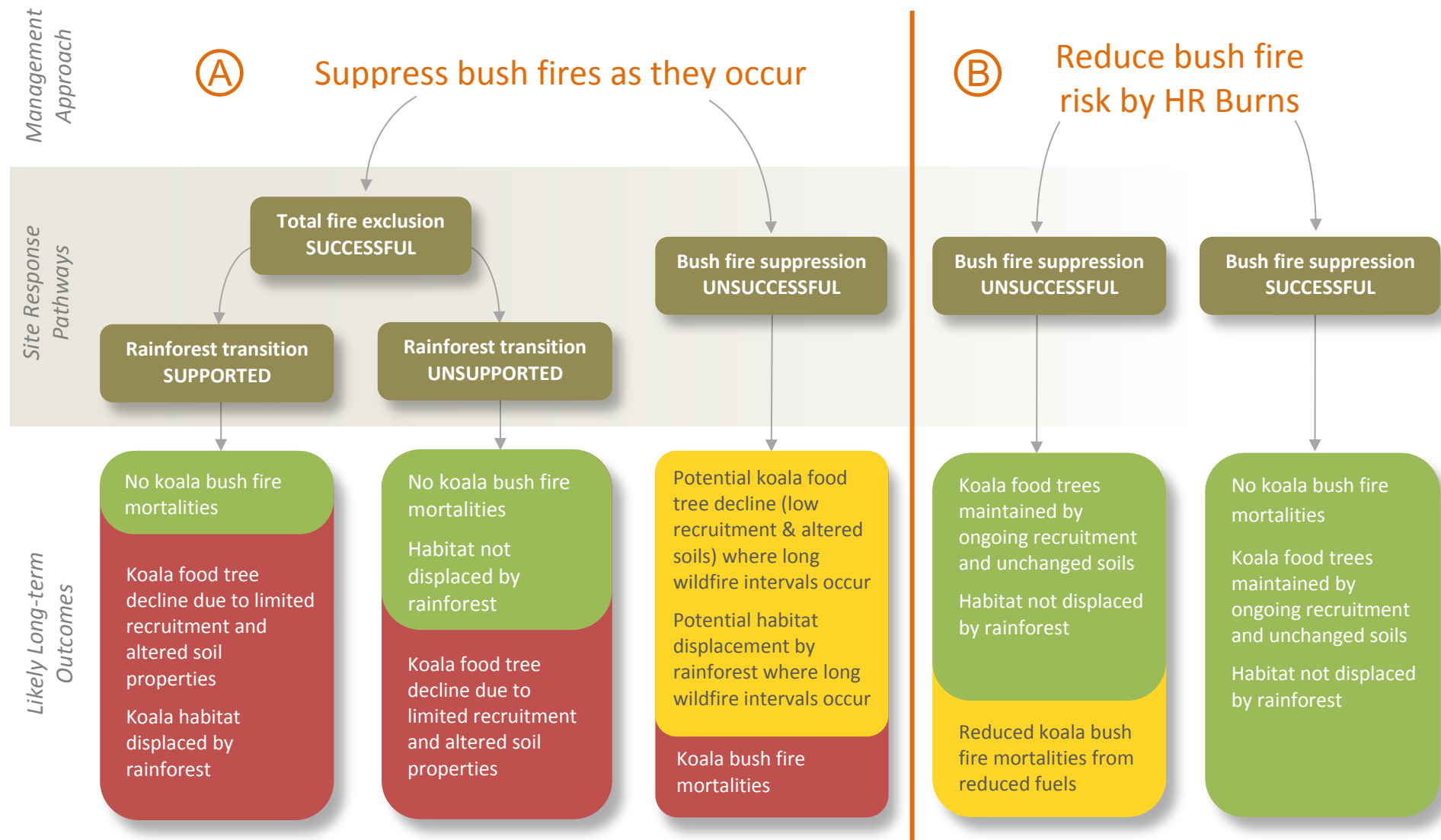


Figure 11. Predicted long-term outcomes from different fire management approaches: A) existing *reactive* approach, and B) *proactive* approach recommended by this Plan. Site response pathways will vary between sites, and a combination of outcomes is likely across the total area of koala habitat on the Tweed Coast depending on the overall approach deployed. Positive outcomes are shown in green, negative outcomes in red, and intermediate or mixed outcomes in yellow.

The forest habitats of the koala are among the most fire-prone ecosystems on earth (Whelan 1995), making *total* fire-exclusion an unrealistic and undesirable management goal. Attempts to exclude fire from these forests typically allow excessive accumulation of fuels, priming the koala habitat for catastrophic bush fire in extreme fire weather, thereby maximizing the likelihood of koala mortalities. Conversely, well-planned HR burns present a very low risk to individual koalas and their foraging resources. Low to moderate intensity HR burns are restricted to surface litter and understorey vegetation, with the canopy providing refuge for koalas and other arboreal mammals above the scorch height of the flames (**Figure 12**).

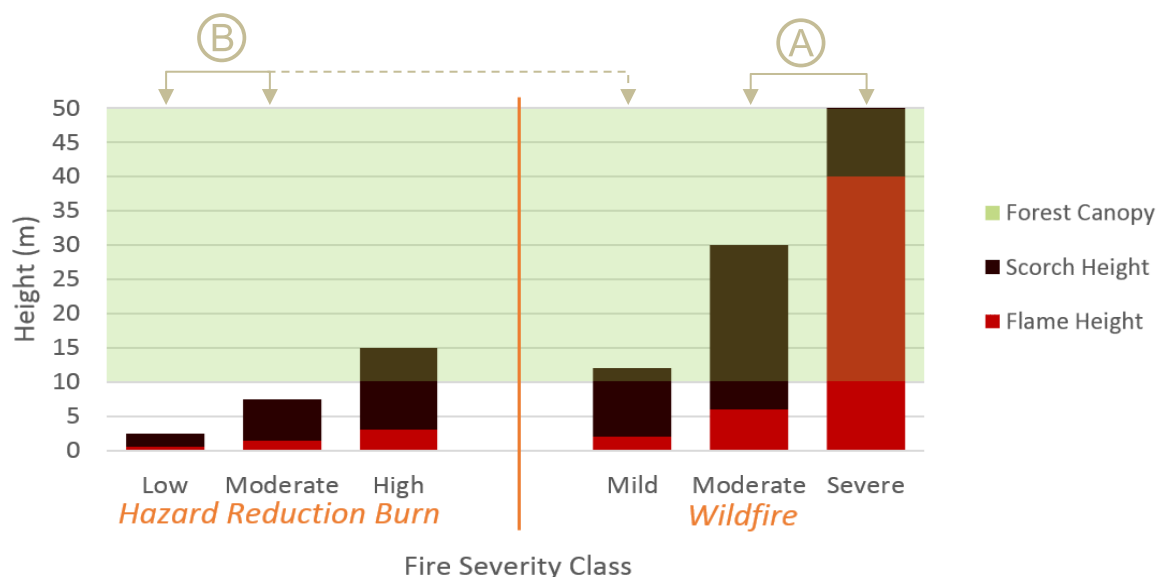


Figure 12. Maximum average flame and scorch heights of different fire severity classes compared to the height of forest canopies on the Tweed Coast. The predominant fire types expected under the fire-exclusion approach (A) maximise canopy impacts, while predominant fire types expected under a hazard reduction burning approach (B) results in minimisation of canopy impacts (adapted from TSC 2004, QPWS 2013, Adams & Attiwill 2011).

Prioritising Hazard Reduction Burns

Prioritising hazard reduction burns in koala habitat should be based on overall bush fire risk to koalas, including fuel hazard and risk of peat fires. Such an assessment has been undertaken in preparing this plan (see **Appendix A**), and allowed development of a *Hazard Reduction Priority Map (Map 5)*. Council will implement works on Council owned and managed lands in accordance with the HR Priority Map. The identified priorities on all other land tenures are for information purposes only. Council will work with adjoining landholders upon request.

Hazard Reduction Burn Guidelines

To compliment this Plan, ‘*Hazard Reduction Burn Guidelines for Koala Habitat on the Tweed Coast*’ have been developed for application to all hazard reduction burns in koala habitat to ensure minimal risk to koalas before during and after burn implementation. The use of HR burns within koala habitat must be undertaken with careful planning. Burns are recommended to be undertaken in mild weather conditions and using strategic burn tactics to limit flame and scorch heights below forest canopies where koalas reside.

The critical factor is to avoid canopy scorch wherever koalas are present at the time of burning. This can be achieved by identifying areas of high risk, and managing these risks by fuel management, strategic burn tactics or exclusion from the burn area. Where these risks cannot be managed the burn should not proceed.

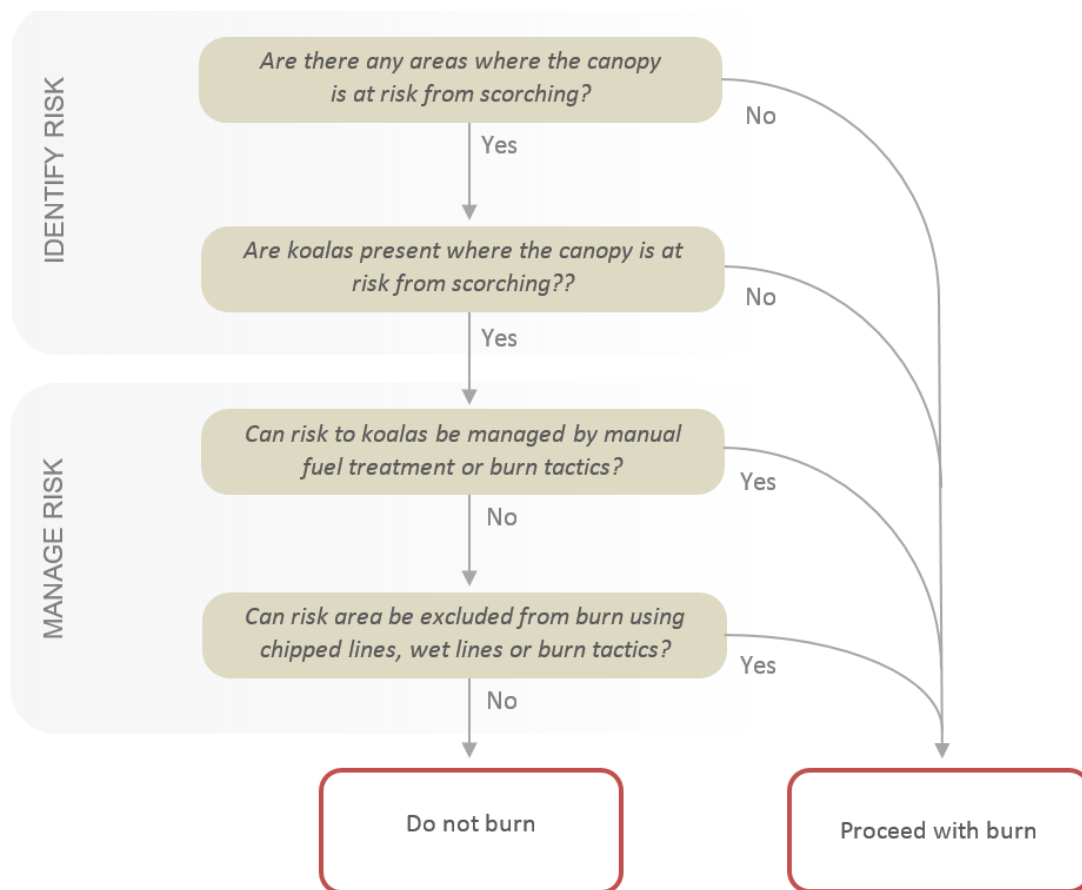


Figure 13. Decision framework for implementing hazard reduction burns in koala habitat.

Reducing not Eliminating Bush Fire Risk

Weather and fuel dynamics in Australian sclerophyll forests are conducive to regular high intensity fires, therefore hazard reduction burning can only realistically be expected to reduce rather than eliminate bush fire risk. Fuel in some vegetation communities can recover to a level capable of sustaining fire, albeit low intensity, within a few years of being burnt, especially in extreme fire weather.

It is reasonable, however, to manage natural areas to minimise the risk of bush fire, reducing their frequency, intensity, extent and rate of spread, and thereby improving fire suppression capabilities. Research indicates that a halving of bush fire risk in these forests is likely to require treatment rates of 7-10% of the area of the landscape per annum (Bradstock *et al.* 2012), which in the study area represents c. 190 -280 ha/yr. However, over the last 10 years, HR burns have averaged only 0.25 ha/yr. Therefore, a radical increase in HR burning will be required to reduce bush fire risk in the study area. While this will be a challenging goal, comparable rates of HR burning occur in other coastal LGAs in NSW (e.g. Hawkesbury LGA) and the annual rate could periodically be met by large, single, well-planned burns.

Adaptive Management

While it is important to prescribe hazard reduction burns to minimise the likelihood of high intensity fires in koala habitat, it is also important to consider the possible long-term impacts of such prescriptions on koala habitat, as well as monitor the effectiveness of such management. It is acknowledged that low intensity hazard reduction burns may not be of sufficient intensity to ensure recruitment of all species of koala food trees and other flora species of conservation significance (Auld and O'Connell 1991). Additionally, many sites in the study area have already undergone significant change following long periods without fire and weed invasion, and the response of these altered ecosystems to the reintroduction of fire is uncertain. To address these uncertainties, monitoring and adaptive management will be necessary to determine fire management strategies that best meet the objectives of protecting people and property, reducing the risk of injury or death to koalas, long-term

conservation of koala habitat and other biodiversity values. Adaptive management is further addressed in **section 4**.

Alternatives to Hazard Reduction Burns

Hazard reduction burns may not always be feasible or achievable to adequately manage risk to koalas. In these cases alternate strategies such as the installation of new fire trails and community education may be necessary as discussed in the relevant strategies herein.

Mechanical hazard reduction may be appropriate along bushland edges that adjoin fire-sensitive assets (e.g. residential areas), and typically involves mechanical clearing, mowing, and under-scrubbing. While the primary objective of these zones is usually to prevent bush fire leaving bushland areas and damaging adjacent to built assets, the zones themselves may provide important koala habitat where they include koala food trees. Any mechanical hazard reduction works in koala habitat must minimise risks to koalas.

Mechanical hazard reduction works may also be used to reduce the risk of bush fire entering koala habitat from developed areas, such as recreational and camping areas, or roads. HR works in these areas may typically involve slashing of grassy areas between the hazard and the bushland.

AIMS

By or before 2026, to have:

- an enhanced network of 'strategic fire advantage zones' to protect both the community and the koala populations.
- a well-coordinated system of hazard reduction burning operating throughout koala habitat areas, and applying fire to 5-10% of koala habitat per annum.
- at least 60% of koala habitat within recommended fire interval thresholds for ecological management.

EXISTING SITUATION

Existing fire-exclusion policies exacerbate the major fire management issues for the Tweed Coast koala, including high intensity bush fire, peat fire and habitat decline.

*Approx. 40% of koala habitat in the KMA is beyond fire-interval thresholds for biodiversity conservation and is likely to have high overall fuel hazard (**Map 4**).*

Annual HR burn extent is 0.25 ha/yr over the last 10 years

GUIDELINES & SAFEGUARDS

Detailed guidelines are included in the attached 'Hazard Reduction Burn Guidelines for Koala Habitat on the Tweed Coast' developed under this Plan.

Additional guidelines are also contained in Planned Burn Guidelines' of the QPWS (2013).

Fuel hazard will be determined using the 'Overall Fuel Hazard Assessment Guide' (Hines et al. 2010).

See the 'Hazard Reduction Priorities Map' to determine areas requiring a planned burn (Map 5; ensure access to current version).

Hazard reduction burning should ideally aim to treat 7-10% per annum of koala habitat in order to halve bush fire risk (Bradstock et al. 2012).

Planned burning interval should aim for a diversity of age classes across koala habitat, and will be guided by the biodiversity thresholds as specified in QPWS 2013.

ACTIONS

Disseminate "Hazard Reduction Burn Guidelines for Koala Habitat on the Tweed Coast" to all land and fire management agencies in the KMA.

Implement hazard reduction program in coordination with other fire agencies in accordance with the 'Hazard Reduction Burn Guidelines for Koala Habitat on the Tweed Coast'

Undertake systematic review of koala habitat mapping to improve hazard reduction planning.

The Hazard Reduction Priority Map is to be reviewed at least every 2 years (ideally annually) by GIS analysis incorporating updated fire records and fire interval status.

Maintain roadside slashing regime along roadsides adjacent to occupied koala habitat. Ensure key areas are treated at start of main bush fire period (early August) and again in October where appropriate.

BUSH FIRE RESPONSE

BACKGROUND INFORMATION

A Bush Fire Response Plan is a set of procedural guidelines and key logistical information designed to ensure quick and effective mobilisation of resources in the event of a bush fire. While fire agencies are currently guided by existing incident response plans (NPWS), or plans developed during the incident (NSW RFS), limited consideration is given to koalas in developing these plans. This Plan however, seeks to promote increased consideration of koalas during bush fire suppression activities by developing a set of koala specific bush fire response procedures to support the existing bush fire response planning framework.

To compliment this Plan, *Koala Bush Fire Response Procedures* have been prepared to cover all areas of Koala Habitat in the KMA, and includes the following:

- key operating procedures
- contact details for staff, other agencies, and resources
- maps to assist with bush fire suppression priority

The protection of human life and property are the overriding priorities for fire management agencies during bush fire suppression, with protection of koala values being secondary considerations where circumstances allow. While the fire agencies have agreed to notify Council in the event of bush fire in koala habitat, it is the responsibility of Council to advise the fire agencies and other stakeholders of all relevant koala-specific bush fire response procedures (**Figure 14**).

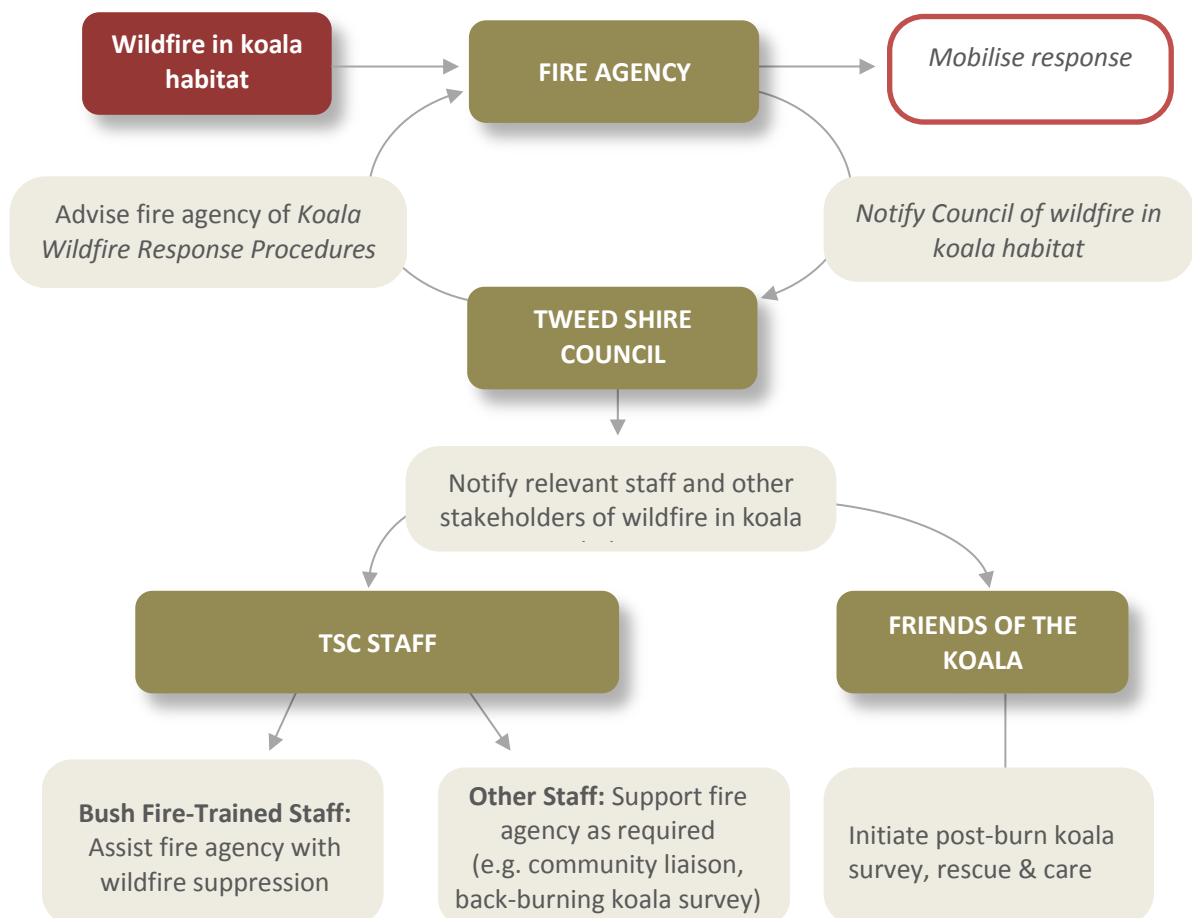


Figure 14. Implementation of Bush Fire Response Procedures.

Fire Agency Response

The Rural Fire Service Far North Coast Area has made a local commitment to maximise response, within available resource limits, to all bush fire incidents in koala habitat. Where fires in koala habitat are on Council managed lands and are large enough to require more than two fire trucks and assignment of an Incident Controller, notification of the incident will be provided to the nominated Council officer. Any consideration of koala values by fire agencies during bush fire incidents in koala habitat will be informed by a single-sheet Koala Bush Fire Response Procedure (KBFRP). The KBFRP includes a **Suppression Priority Map** that outlines the priorities for bush fire suppression based on hazard reduction and ecological considerations after the requirements for the protection of life and property have been satisfied. A Suppression Priority Map shows the following categories:

- Acceptable – can allow bush fire to burn, because it can be managed to meet current hazard reduction objectives and / or ecological outcomes
- Not desirable – will not meet planned burn objectives and may impact on longer term objectives and ecological outcomes, but consequences are manageable or acceptable
- Unacceptable – suppress bush fire if at all possible.

In practice, a Suppression Priority Map provides the Incident Management Team with a quick reference guide to the environmental issues relating to a bush fire. For example, if a bush fire within an “acceptable” area is of low to moderate intensity and of no threat to life and property, consider taking advantage of the opportunity and monitor the fire within acceptable boundaries, rather than active and possibly expensive suppression action. This approach was successfully applied to a recent bush fire at Cabarita (September 2016), where earlier preparations for an HR burn on the site made it safe to allow the bush fire continue throughout the block. However, where predicted weather is serious and fire threats are high, immediate active suppression is always the priority.

Tweed Council & Other Stakeholders

It is the responsibility of Tweed Shire Council to advise fire agencies, relevant staff and other agency stakeholders of the koala-specific Bush Fire Response Procedures.

Involvement of Tweed Council staff may include: i) bush fire-trained staff assisting fire agencies with on-ground bush fire suppression, and ii) other staff supporting fire agencies as required, including community liaison, and coordination of koala searches immediately prior to back burning operations in order to identify potentially vulnerable koala individuals. The suitability of Tweed Council staff will be at the discretion of the agency's Incident Controller.

Post-fire survey, rescue and rehabilitation of koalas injured in bush fires can play an important role in reducing mortality from bush fire. In NSW wildlife welfare and carer groups are licensed to rescue, rehabilitate and release native fauna under the *National Parks and Wildlife Act 1974*. Friends of the Koala Inc. are responsible for koala rescue and care on the Tweed Coast. Volunteer koala rehabilitators are supported by local veterinarians as well as wildlife veterinary teams at Currumbin Wildlife Sanctuary (Currumbin, Qld) and Australian Wildlife Hospital (Beerwah, Qld). Post fire surveys by koala carers specially trained and equipped to enter burnt areas occurs in the Port Macquarie area and should be considered on the Tweed Coast.

AIMS

By or before 2017, to have koalas given due consideration during all bush fire suppression operations in koala habitat.

EXISTING SITUATION

Koala-specific bush fire response recommendations are currently limited to NPWS Fire Management Strategies.

Incident control teams do not have ready access to information relating to:

- distribution of koala habitat*
- fire-interval threshold information (except NPWS estate)*
- distribution of peat soils*
- contact details for koala rescue and rehabilitation organisations*

GUIDELINES & SAFEGUARDS

Consideration of koalas during bush fire incidents are to follow the Koala Bush Fire Response Procedures

The Koala Bush Fire Response Procedures should avoid duplicating information already available to fire agencies during incident planning (e.g. fire trails, water points, threatened property, aboriginal sites).

ACTIONS

Fire agencies are to be made aware of the Koala Bush Fire Response Procedures and encouraged to give them due consideration during all bush fire events in koala habitat.

Tweed Council staff are to be encouraged to undertake training in bush fire operations, community liaison and pre-back burning koala surveys.

Investigate options for uploading koala-related mapping layers to RFS online 'bush fire incident management tool'.

The information provided in the Koala Bush Fire Response Procedure, including on the maps, is to be reviewed and, if necessary, updated annually prior to the 'bush fire season'.

The Suppression Priority Map is to be reviewed annually in line with recent burns and time since last burn.

EDUCATION, MONITORING & RESEARCH

BACKGROUND INFORMATION

Overview

While there is general community awareness that bush fire is a major threat to the Tweed Coast koala, the crucial role of hazard reduction burns in reducing this threat, and in maintaining koala habitat is poorly understood. And while the importance of hazard reduction burns is better understood by many land management agencies, there are many information gaps in the use of fire as a land management tool in complex landscapes such as the Tweed Coast.

Community Awareness

A large proportion of koala habitat in the study area occurs on private land, where improved fire management not only benefits koala conservation, but can directly increase the safety for human life and property. Council is seeking to realise these mutual benefits by increasing landholder engagement in bush fire planning as a key component of the Plan. A range of opportunities exists for Council and the fire agencies to assist landowners with improved fire management on their properties, including providing information and assistance with property-wide fire planning, hazard reduction approval and the maintenance of fire access and static water supplies. Education and extension programs assist landowners to understand what they can do to support appropriate fire management on their properties and on the Tweed Coast.

It is also critical that the wider community understand and support the fire management strategies of this Plan. Currently, there is a common view in the wider public that all fires are largely detrimental to koalas and their habitat, and that all fire should therefore be excluded. This view is in stark contrast to the contemporary science that underpins the management strategies in this Plan, and fostering a greater understanding of the important role of fire in koala conservation is essential to the long-term future of the Tweed Coast koala. Accordingly, Council will develop an education program to promote greater community awareness and ongoing education as a strategy to improve fire management within koala habitat.

Monitoring, Research and Adaptive Management

This Plan provides for ongoing monitoring and adaptive management to ensure planning and management are responsive to new information and changing circumstances. For example, while hazard reduction burns address many complimentary management objectives, it is essential that the effectiveness and long-term impacts of such management are regularly monitored. Such research would contribute to the development of fire management strategies that best meet objectives for minimising the risk to people, property and koalas, whilst conserving koala habitat and associated plant and animal communities.

AIMS

By or before 2026, to have:

- increased the Tweed community's awareness of the role of bush fire and prescribed fire on koalas and koala habitat.
- increase landholder engagement in bush fire planning and management within koala habitat areas.

EXISTING SITUATION

A large proportion of koala habitat occurs on private land, and effective landholder engagement is therefore critical to improved fire management.

The crucial role of hazard reduction burns in reducing bush fire and maintaining koala habitat is poorly understood in the general community.

Many aspects of ecological fire management, such as the appropriate fire regimes required for ongoing recruitment of koala food trees, are not well understood.

GUIDELINES & SAFEGUARDS

None identified

ACTIONS

Council, in conjunction with fire agencies, will develop and deliver a landholder and community education program (e.g. community workshops, landholder information sessions, brochures, online material) that will:

- outline the value of the fire management activities for koala and biodiversity conservation, and overall fire safety for human life and property;*
- promote active landholder engagement in bush fire planning on privately-owned land and outline what landowners can do to support appropriate fire management on their properties and on the Tweed Coast;*
- provide information on the hazard reduction approvals process; and*
- encourage landowners to maintain access and static water supplies on their properties.*

Council will encourage improved coordination among fire and land management agencies through:

- active sharing of information relating to current koala distribution and aims of fire management by Council with other land managers; and*
- offering koala awareness training for bush fire management personnel including those involved with the preparation of the Far North Coast Bush Fire Risk Management Plan and assessors of hazard reduction applications.*

Encourage and facilitate monitoring and/or research focusing on topics where current information is inadequate or incomplete, including:

- Recruitment of koala food trees following bush fire and hazard reduction burns;*
- Habitat usage patterns following bush fire, prescribed burns and long-term fire exclusion;*
- Response of encroaching rainforest trees (including environmental weeds such as Camphor Laurel, Umbrella Tree, Privet) to bush fire and HR burns; and*
- Emerging koala survey techniques, such as such as the use of koala detection dogs or unmanned aerial vehicles (i.e. drones) fitted with infrared cameras.*

Council will actively seek research-oriented grants to fund research projects.

Council will explore opportunities for collaboration with research institutions and other agencies as they arise, including involvement of final year and postgraduate University students, University staff and volunteers.

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7 Appendices

Appendix A. GIS Methods

Bush fire Risk Assessment

A bush fire risk assessment was developed to determine hazard reduction priorities in the study area. The overall bush fire risk to koalas was determined by GIS analysis of the following risk factors across each area of koala habitat:

- **fuel hazard** - as derived from comparing time since last fire with recommended fire-interval for each vegetation type;
- **peat fire risk**

Koala activity levels were excluded as a factor in the analysis due to the large variability observed between 2010 (Phillips *et al.* 2011) and 2015 (TSC 2015b). Further, whilst mapped koala meta populations identify those areas of most significant koala activity, koalas are known to occur throughout the landscape. Site based assessment of koala activity is required for HR planning and is considered the most appropriate approach to ensuring accurate consideration of koala activity for this purpose.

Fuel Hazard (Fire Interval Status)

Fire interval status was used as a proxy for fuel hazard, and was derived by comparing time since last fire with recommended fire-interval for each vegetation type. The use of fire interval status as a proxy for fuel hazard was based on the relationship between surface fuel load and recommended fire interval (**Figure 1**). The use of fire interval status in the analysis also ensured alignment of bush fire risk management with the maintenance of ecological processes.

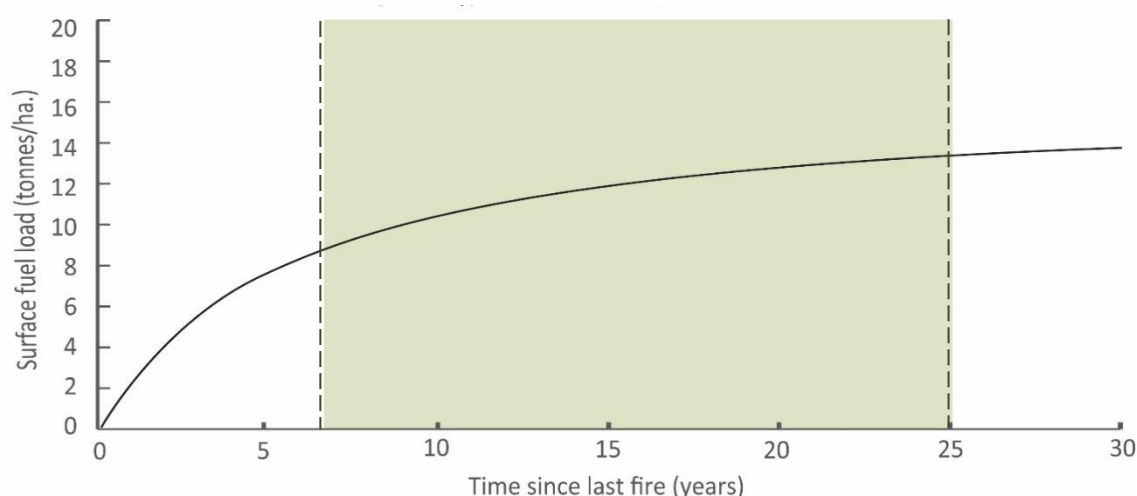


Figure 1. Surface fuel load at time since last fire (line) compared with recommended fire intervals for biodiversity conservation (shaded area) for Dry Sclerophyll Forest (adapted from Gould *et al.* 2007 & QPWS 2013).

Peat Fire Risk

Risk of peat fires is determined by identifying areas of koala habitat that are associated with soils or vegetation types indicative of peat formation (**Table 1**).

Table 1. Soil and vegetation types indicative of peat formation and peat fire risk.

Indicative Soil Landscapes (Morand 1994)
<i>Cobaki (and variants)</i>
<i>Ukerebagh</i>
<i>Kingscliff</i>
<i>Pottsville</i>
Indicative Vegetation Types (TSC 2004)
<i>Swamp She-oak Closed Forest to Woodland</i>
<i>Fernland / Forbland (Murray & James 1998 Study Area Only)</i>
<i>Sedgeland / Rushland (Murray & James 1998 Study Area Only)</i>
<i>Broad-leaved Paperbark / Swamp She-oak Closed Forest to Woodland</i>
<i>Broad-leaved Paperbark Closed Forest to Woodland</i>
<i>Broad-leaved Paperbark + Eucalyptus spp. +/- Swamp Box Closed Forest to Woodland</i>
<i>Wet Heathland to Shrubland</i>

Bush Fire Risk Score and Hazard Reduction Priority

All areas of koala habitat are assigned risk scores consistent with the relevant class of *fire interval status* and *peat fire risk* (Table 2). And the combined risk score for each area of habitat is then used to determine the bush fire risk and hazard reduction priority (Table 3)

Table 2. Risk score assigned to fire interval status and peat fire risk classes.

Class	Risk Score
<i>Fire Interval Status (Fuel Hazard)</i>	
<i>Below Threshold</i>	0
<i>Within Threshold</i>	2
<i>Near Fire-exclusion</i>	3
<i>Fire Excluded</i>	4
<i>Peat Fire Risk</i>	
<i>Peat soils unlikely</i>	0
<i>Peat soils likely</i>	1

Table 3. Total risk score, bush fire risk and hazard reduction priority.

Total Risk Score	Bush Fire Risk	Hazard Reduction Priority	Rationale
≤1	Low Risk	Exclude Fire	Vegetation is below ecological thresholds for fire.
2	Moderate Risk	Low Priority	Vegetation is ready for fire, however is in the earlier end of the burn window, has relatively low fuel hazard, and is not a peat fire risk.
3	High Risk	Moderate Priority	Vegetation is: i) nearly overdue for fire (approaching the end of the burn window) and has a moderate fuel hazard, or ii) is in the earlier end of the burn window but presents a peat fire risk.
≥4	Very High Risk	High Priority	Vegetation is: i) overdue for fire and has a high fuel hazard, or ii) is nearly overdue for fire (moderate fuel hazard) and also presents a peat fire risk.

Fire Interval Status

Overview of approach

To determine the fire interval status across the study area, GIS analysis compared *modern fire history* and *recommended (historic) fire intervals* for mapped native vegetation.

Preparation of existing fire history and vegetation spatial datasets

FIRE HISTORY DATA

The fire history datasets of the NSW Rural Fire Service (RFS) and the NSW National Parks and Wildlife Service (NPWS) were used as the basis for modern fire history mapping to determine time since last fire across the study area (**Table 4**). The publicly available datasets were acquired under data usage agreements with the relevant data custodians (i.e. RFS and NPWS). All datasets span all land tenures across the study area. These datasets were clipped to the spatial extent of the study area before being aggregated to form a single 'Modern Fire History' layer.

Table 4. Fire history datasets used to determine time since last fire across the study area.

Dataset Name	Custodian	Description
<i>FireHistoryJanuary2015</i>	NPWS	Defines the area of all fires across all tenures as mapped by the NSW NPWS to January 2015.
<i>WildfireHistory</i>	RFS	Defines the final area of fires mapped in the NSW RFS Incident Coordination Online (ICON) to April 2015. Fire History is derived from incidents mapped by NSW Bush Fire agencies (NPWS, NSW RFS, Fire & Rescue NSW).
<i>WildfireHistory_NDMP</i>	RFS	Defines the areas of fire events based on Landsat imagery analysis of fire scar.
<i>201415fires</i>	RFS	Fire areas mapped for the 2014/15 financial year to 15/04/2015 which had not been added to <i>Wildfirehistory</i> .
<i>HRWorksActualArea</i>	RFS	Mapped area for hazard reduction burns to 15/04/2015.
<i>HRWorksProposedArea</i>	RFS	Mapped area of proposed hazard reduction burns to 15/04/2015. May also contain completed burns not yet entered into <i>HRWorksActualArea</i> .

It must be noted that limitations exist within fire history datasets that may cause both over- and underestimation of fire extent, and thus frequency (Tunstall *et al.* 1998; Price *et al.* 2003). The datasets used for this study may not include some smaller fires, particularly on private lands, potentially underestimating fire frequency on some sites. Conversely, fire frequency is overestimated where mapped burn areas erroneously include unburnt patches (Price *et al.* 2003), as was confirmed for several large fire events in the study area by analysis of post fire aerial photography.

VEGETATION DATA

Vegetation distribution across the entire study area was derived from the Tweed Shire Council vegetation mapping dataset (tweed_LGA_VISmap_673), last updated in 2009. The dataset was clipped to the spatial extent of the study area. Polygons with cover types not comprising native vegetation (e.g. rock, water, pasture, or vegetation where introduced species comprise >50% of the dominant stratum) were identified and excluded from further analysis.

Vegetation types [field:VEGTYP] were then assigned to koala habitat classes based on the habitat classes of Phillips *et al.* (2011; **Table 5**). The resulting class assignments across the study area shown in **Table 6**.

Table 5. Habitat class definitions for Coastal Koala Habitat mapping within Tweed Shire (after Phillips *et al.* 2011).

Habitat Class	Definition
Primary Habitat	Areas of forest and/or woodland wherein primary food tree species comprise the dominant or co-dominant (i.e. $\geq 50\%$) overstorey tree species.
Secondary Habitat (Class A)	Habitat areas of forest and woodland wherein primary food tree species are present but not dominant or co-dominant and usually (but not always) growing in association with one or more secondary food tree species.
Secondary Habitat (Class B)	Areas of forest and woodland wherein primary food tree species are absent, habitat containing secondary and/or supplementary food tree species only.

Table 6. Assignment of vegetation types (tweed_LGA_VISmap_673/VEGTYP) to koala habitat classes.

Vegetation Type	Koala Habitat Class
<i>Banksia Dry Sclerophyll Open Forest to Shrubland</i>	Secondary Habitat (Class A)
<i>Blackbutt Open Forest Complex</i>	Secondary Habitat (Class B)
<i>Broad-leaved Paperbark / Swamp She-oak Closed Forest</i>	Secondary Habitat (Class A)
<i>Broad-leaved Paperbark + Eucalyptus spp.+/- Swamp Forest</i>	Secondary Habitat (Class A)
<i>Broad-leaved Paperbark Closed Forest to Woodland</i>	Secondary Habitat (Class A)
<i>Brush Box Open Forest</i>	Secondary Habitat (Class B)
<i>Coastal Acacia Communities</i>	Secondary Habitat (Class A)
<i>Coastal Blackbutt Open Forest to Woodland</i>	Secondary Habitat (Class A)
<i>Coastal Forest Red Gum Open Forest to Woodland</i>	Primary Habitat
<i>Coastal Pink Bloodwood Open Forest to Woodland</i>	Secondary Habitat (Class A)
<i>Coastal Scribbly Gum Open Forest to Woodland</i>	Secondary Habitat (Class A)
<i>Coastal Swamp Box Open Forest to Woodland</i>	Secondary Habitat (Class A)
<i>Coastal Swamp Mahogany Open Forest to Woodland</i>	Primary Habitat
<i>Coastal Tallowwood Open Forest to Woodland</i>	Primary Habitat
<i>Swamp She-oak Closed Forest to Woodland</i>	Secondary Habitat (Class A)

7.1.1 Assignment of vegetation types to fire vegetation groups

Vegetation types were then assigned to one of six *fire vegetation groups* (e.g. Wet Open Forest Shrubby) of the *Planned Burn Guidelines: Southeast Queensland Bioregion of Queensland* (QPWS 2013; Table 7). These guidelines were used as they were specifically developed for the broader region of the study area, they specifically consider vegetation change potential, and they are recommended for use in the study area region by the Northern Rivers Regional Biodiversity Management Plan (DECCW 2010).

The fire vegetation groups of QPWS (2013) subdivide wet and dry open forest into different subclasses based on understorey composition. Assignment to these fire vegetation groups involved analysis of equivalent Forest Ecosystem Descriptions' (DECC 2004) for each vegetation type as defined in the Tweed Vegetation Management Strategy equivalency table (Appendix 4, TSC 2004). Classification involved assessment of the relative abundance of I-species and T-species (after Noble & Slatyer 1980) as documented in vegetation type descriptions. Watson (2006) defines I-species as small, short-lived, light-dependent species that recruit following fire and decrease in abundance with fire exclusion, and T-species as large, long-lived, soft-leaved species which recruit between fires and increase in abundance with fire exclusion. Final classification and recommended fire intervals are given in **Table 7**.

Table 7. Classification of vegetation types to the *fire vegetation groups* of QPWS (2013).

Vegetation Type [VEGCODE + VEGTYP]	Fire Vegetation Group (FVG; QPWS 2013)	Min. Fire Interval	Max. Fire Interval	Justification for FVG Assignment
201 Blackbutt Open Forest Complex	Wet Open Forest Shrubby	7	25	Equivalent to Forest Ecosystem 95 (Northern Moist Blackbutt; DEC 2004) dense understorey with Forest Oak (<i>Allocasuarina torulosa</i>) and Coffee Bush (<i>Breynia oblongifolia</i>) occurring frequently along with many other moist forest species. The ground layer is varied with Blady Grass (<i>Imperata cylindrica</i>), Wiry Panic (<i>Entolasia stricta</i>), Spiny-headed Mat-rush (<i>Lomandra longifolia</i>) and Bracken (<i>Pteridium esculentum</i>) occurring frequently, but ferns such as Gristle Fern (<i>Blechnum cartilagineum</i>) and Rough Maidenhair (<i>Adiantum hispidulum</i>) are sometimes prominent. <i>Vernonia cinerea</i> (68), <i>Glycine clandestina</i> (68) (DEC 2004).
301 Coastal Pink Bloodwood Open Forest to Woodland	Wet Open Forest Shrubby	7	25	Occurs as either WSF or DSF (Ecograph 2004). WSF occurrences likely to be State 2. Equivalent to Forest Ecosystem 23 (Coast Range Bloodwood-Mahogany; DEC 2004) <i>Allocasuarina torulosa</i> (80), <i>Pimelea linifolia</i> (80), <i>Persoonia stradbokensis</i> (80), <i>Gompholobium pinnatum</i> (70), <i>Leucopogon lanceolatus</i> (50), <i>Entolasia stricta</i> (90), <i>Cymbopogon refractus</i> (80), <i>Dianella caerulea</i> (80), <i>Imperata cylindrica</i> (80), <i>Lepidosperma laterale</i> (70), <i>Pratia purpurascens</i> (70), <i>Panicum simile</i> (70), <i>Digitaria parviflora</i> (60), <i>Patersonia glabrata</i> (60), <i>Aristida vagans</i> (60)
308 Coastal Tallowwood Open Forest to Woodland	Wet Open Forest Shrubby	7	25	Equivalent to Forest Ecosystem 146 (Tallowwood; DEC 2004) The ground layer is a mix of grasses, forbs and ferns such as Blady Grass (<i>Imperata cylindrica</i>), Kangaroo Grass (<i>Themeda australis</i>), Spiny-headed Mat-rush (<i>Lomandra longifolia</i>), Maidenhair (<i>Adiantum aethiopicum</i>) and Rasp Fern (<i>Doodia aspera</i>).
207 Brush Box Open Forest	Wet Open Forest RF	20	-	Equivalent to Forest Ecosystem 103 (Northern Wet Brushbox; DEC 2004) T-species dominate the wet understorey which includes rainforest species such as Murrogon (<i>Cryptocarya microneura</i>), Scentless Rosewood (<i>Synoum glandulosum</i>), Bolwarra (<i>Eupomatia laurina</i>) and Celery Wood (<i>Polyscias elegans</i>). Vines such as Water Vine (<i>Cissus antarctica</i>) and Native Yam (<i>Dioscorea transversa</i>) are common (DEC 2004).
305 Coastal Swamp Mahogany Open Forest to Woodland	Melaleuca Communities - Heathy	8	12	Both forest types dominated by <i>Eucalyptus robusta</i> are grouped with <i>Melaleuca quinquenervia</i> communities (RE ID 8.2.7 & 12.3.4) in the Regional Ecosystem Description Database (Queensland Herbarium 2015).
306 Coastal Scribbly Gum Open Forest to Woodland	Dry Open Forest Shrubby	7	25	Equivalent to Forest Ecosystem 74 (Lowlands Scribbly Gum; DEC 2004) - where there is often a scattered understorey of Tea-tree (<i>Leptospermum polygalifolium</i>), <i>Melaleuca sieberi</i> and <i>Banksia oblongifolia</i> . The ground layer is diverse and includes a number of swamp elements such as Feather Plant (<i>Baloskion tetraphyllum</i>) and the twig-rushes (<i>Baumea articulata</i> and <i>B. rubiginosa</i>) as well as Wiry Panic (<i>Entolasia stricta</i>) and Spiny-headed Matt-rush (<i>Lomandra longifolia</i>).
307 Coastal Blackbutt Open Forest to Woodland	Dry Open Forest Shrubby	7	25	Equivalent to Forest Ecosystem 37 (Dry Heathy Blackbutt - Bloodwood; DECC 2004) This ecosystem has a moderately dense understorey composed of predominantly heathy shrubs elements such as banksias (<i>Banksia spp.</i>), egg and bacon peas (<i>Pultenaea spp.</i>), Rice Flower (<i>Pimelea linifolia</i>) and Geebung (<i>Persoonia stradbokensis</i>). The ground layer is a mixture of forbs, ferns and grasses such as Wiry Panic (<i>Entolasia stricta</i>), Blue Flax Lily (<i>Dianella caerulea</i>) and Bracken (<i>Pteridium esculentum</i>).
309 Coastal Swamp Box Open Forest to Woodland	Melaleuca Communities - Heathy	8	12	Equivalent to Forest Ecosystem 112 (Paperbark; DECC 2004) This equivalent forest ecosystem groups all 'Paperbark' communities irrespective of understorey composition. In the absence of understorey data, all 'Paperbark' communities have been assigned to the 'Melaleuca Communities - heathy' group, as it provides an intermediate

Vegetation Type [VEGCODE + VEGTYP]	Fire Vegetation Group (FVG; QPWS 2013)	Min. Fire Interval	Max. Fire Interval	Justification for FVG Assignment
304 Coastal Forest Red Gum Open Forest to Woodland	Dry Open Forest Grassy	3	6	minimum fire interval (i.e. 8 years), but lower maximum fire interval to provide an early trigger for the potential of peat fire risk. The understorey and actual fire interval at a site will be confirmed as part of the routine site assessment prior to applying hazard reduction burns. Equivalent to Forest Ecosystem 73 (Lowlands Red Gum; DEC 2004) There is a relatively open understorey with Red Ash (<i>Alphitonia excelsa</i>) common, and a ground layer dominated by species such as Blady Grass (<i>Imperata cylindrica</i>), Spiny-headed Matt-rush (<i>Lomandra longifolia</i>) and Kangaroo Grass (<i>Themeda australis</i>). All <i>E. tereticornis</i> communities in Northern Rivers Regional Biodiversity Management Plan listed as Dry Sclerophyll Forest and a few grassy Dry Sclerophyll Woodlands.
401 Broad-leaved Paperbark Closed Forest to Woodland	Melaleuca Communities - Heathy	8	12	Equivalent to Forest Ecosystem 112 (Paperbark; DECC 2004) This equivalent forest ecosystem groups all 'Paperbark' communities irrespective of understorey composition. In the absence of understorey data, all 'Paperbark' communities have been assigned to the 'Melaleuca Communities - heathy' group, as it provides an intermediate minimum fire interval (i.e. 8 years), but lower maximum fire interval to provide an early trigger for the potential of peat fire risk. The understorey and actual fire interval at a site will be confirmed as part of the routine site assessment prior to applying hazard reduction burns.
402 Broad-leaved Paperbark / Swamp She-oak Closed Forest to Woodland	Melaleuca Communities - Heathy	8	12	Equivalent to Forest Ecosystem 112 (Paperbark; DECC 2004) This equivalent forest ecosystem groups all 'Paperbark' communities irrespective of understorey composition. In the absence of understorey data, all 'Paperbark' communities have been assigned to the 'Melaleuca Communities - heathy' group, as it provides an intermediate minimum fire interval (i.e. 8 years), but lower maximum fire interval to provide an early trigger for the potential of peat fire risk. The understorey and actual fire interval at a site will be confirmed as part of the routine site assessment prior to applying hazard reduction burns.
403 Broad-leaved Paperbark + Eucalyptus spp. +/- Swamp Box Closed Forest to Woodland	Melaleuca Communities - Heathy	8	12	Equivalent to Forest Ecosystem 112 (Paperbark; DECC 2004) This equivalent forest ecosystem groups all 'Paperbark' communities irrespective of understorey composition. In the absence of understorey data, all 'Paperbark' communities have been assigned to the 'Melaleuca Communities - heathy' group, as it provides an intermediate minimum fire interval (i.e. 8 years), but lower maximum fire interval to provide an early trigger for the potential of peat fire risk. The understorey and actual fire interval at a site will be confirmed as part of the routine site assessment prior to applying hazard reduction burns.
601 Swamp She-oak Closed Forest to Woodland	Coastal Fringing Forests	6	7	Equivalent to Forest Ecosystem 143 (Swamp Oak; DECC 2004) This equivalent forest ecosystem correlates with the Coastal Fringing Forest (Swamp Oak) Group of QPWS (2013).
310 Banksia Dry Sclerophyll Open Forest to Shrubland	Undetermined	-	-	Equivalent to Forest Ecosystem 5 (Banksia; DECC 2004) Given this type largely comprises mixed regrowth following severe disturbance (e.g. sand mining), the original vegetation formation (and fire vegetation group) cannot be determined from the dataset.
311 Coastal Acacia Communities	Undetermined	-	-	Forest Ecosystem 311 (Wattle; DECC 2004) While QPWS (2013) indicates these communities are generally fire-adapted, fire interval guidelines are not specified.

Determination of fire interval condition

Comparison of modern and historic fire intervals allowed identification of all vegetation as either within or beyond recommended fire interval thresholds. The derived fire record and vegetation datasets were merged into a single layer, allowing determination of the fire interval condition for each vegetation polygon (≥ 0.5 ha.).

Determination of high frequency fire extent

Finally, the extent of high-frequency fire was also calculated, and included areas of fire-dependent vegetation affected by two consecutive fires at an interval shorter than recommended. Areas affected by multiple fire events were first identified, then the interval between events was calculated and manually compared to minimum fire interval thresholds for intersecting vegetation types.