Natural Resources Commission

Cabinet-in-Confidence

Final report
Coastal IFOA operations post 2019/20 wildfires
June 2021



Enquiries

Enquiries about this report should be directed to:

Phone	(02) 9228 4844
E-Mail	nrc@nrc.nsw.gov.au
Postal address	GPO Box 5341, Sydney NSW 2001

Acknowledgement of Country

The Natural Resources Commission acknowledges and pays respect to traditional owners and Aboriginal peoples. The Commission recognises and acknowledges that traditional owners have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. We value and respect their knowledge in natural resource management and the contributions of many generations, including Elders, to this understanding and connection.

Document No. D21/1505

ISBN: 978-1-925204-68-1

List of acronyms

BAM	Biodiversity assessment method
CAR	Comprehensive, adequate and representative
Coastal IFOA	Coastal Integrated Forestry Operations Approval
Commission	the Natural Resources Commission
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
DPIE-EES	Department of Planning, Industry and Environment's Environment, Energy and Science division
DRNSW	Department of Regional NSW
ESFM	Ecologically sustainable forest management
EPA	NSW Environment Protection Authority
FCNSW	Forestry Corporation of NSW
FESM	Fire extent and severity mapping model
FMZ	Forest management zone
FRAMES	Forest Resource and Management Evaluation System
GEEBAM	Google Earth Engine Burnt Area Map
GIS	Geographic Information System
HQ	High quality
IUCN	International Union for the Conservation of Nature
LiDAR	Light detection and ranging imaging
LGA	Local Government Area
'north coast'	Region covering the Upper North East and Lower North East subregions
NSW	New South Wales
RAFIT	FCNSW's Rapid Assessment of Fire Impact on Timber
'south coast'	Region covering the South Coast, Eden and Tumut subregions
SSOCs	Site-specific operating conditions

Table of Contents

Executive Summary

Key findings

Impacts of the 2019/20 wildfires

The 2019/20 wildfires were unprecedented in their scale, extent of high and extreme fire severity, and duration. They burnt 4.8 million hectares of land in NSW, including just over 64 percent (around 0.7 million hectares) of the native state forest estate. The wildfires significantly impacted forest ecosystems, including native flora and fauna, soil, and water.

The wildfires extensively impacted communities, with 26 fatalities, 2,476 homes destroyed, loss of other infrastructure and business assets, ongoing physical and mental health impacts, and financial hardship.

Forestry operations in coastal NSW usually occur under the Coastal Integrated Forestry Operations Approval (Coastal IFOA). While the Coastal IFOA reflects best practice forest management for regular conditions, it was not designed to mitigate the risks of harvesting in severely fire-affected landscapes like those from the 2019/20 wildfires. As a result, forestry operations have ceased in many of these areas. In other areas, forestry has continued in a limited fashion under site-specific operating conditions (SSOCs) and voluntary measures, which are intended to be temporary.

The valuable native forest timber industry has also been severely impacted, with wood supply falling sharply in all regions in 2020 as a direct result of the wildfires. The Forestry Corporation of NSW (FCNSW) advised the Commission that, while there have not yet been any mill closures as a direct result of reduced timber supply caused by the wildfires, some are at risk of closure unless supply can be increased and there is certainty of ongoing supply. In regions where wood supply was substantially reduced, there have been reductions in work shifts and some redundancies. Further, FCNSW advised that mitigations employed to date – such as supplementation from private property on the south coast and plantations on the north coast – are no longer available to the extent required to meet wood supply levels.

What the Commission was asked to do

The Natural Resources Commission (the Commission) has been asked through a terms of reference to provide independent, evidence-based advice on pathways back to FCNSW operating under standard Coastal IFOA prescriptions, and recommend ways to give effect to that advice.

The Commission has developed a data-driven risk assessment framework to inform a series of pathways (**Figure 1**). This was developed in consultation with agencies and an independent expert panel, using the best-available scientific evidence. Guided by the expert panel and in line with the principles of ecologically sustainable forest management set out in Part 5B of the *Forestry Act 2012*, the Commission has adopted a conservative approach to assessing risk, setting thresholds, and applying additional measures.

Adopting the recommended risk assessment framework and pathways will give FCNSW and the timber industry more certainty to understand if and when relevant wood supply agreements are likely to be fully met and the short- to long-term impacts on regional businesses and job security. It will also provide transparency to communities about how potential

cumulative impacts of forestry operations in fire-affected landscapes are being managed to allow forests to recover and protect environmental values. Adopting the risk assessment framework will also provide the NSW Government with a repeatable approach based on the latest science to manage risks from future large-scale fires.

The risk assessment framework

The risk assessment framework assigns areas of the Coastal IFOA one of four risk ratings (low, medium, high, and extreme) based on the extent to which standard Coastal IFOA prescriptions can mitigate impacts from the 2019/20 wildfires. These ratings determine what actions can occur in that area.

The framework consists of three gateways, at which different assessments are undertaken. Gateway 1 is a management zone-scale assessment that considers risk across a larger management area. Gateways 2 and 3 are additional local landscape area desktop and field assessments required for medium and high risk management zones before limited harvesting can occur.

In low risk management zones, harvesting can resume under the standard Coastal IFOA prescriptions.[1] In these areas there is sufficient confidence that native forests can withstand the short-term impacts of harvesting and that adequate safeguards were in place through the standard Coastal IFOA prescriptions to protect environmental values over the long-term. Noting that, on average, harvesting is already excluded from approximately 50 percent of local landscape areas to protect important environmental values across the Coastal IFOA region.

In management zones rated as being extreme risk, there is a risk of serious and irreversible harm to environmental values from the cumulative impacts of fire and harvesting. In line with the precautionary principle, harvesting must be temporarily suspended for three years from the time of fire (taken to be February 2020).

Management zones that receive medium or high risk ratings can have limited harvesting once there are sufficient additional temporary refuges (preferably unburnt and lightly burnt forest) retained at the local landscape area to mitigate the impacts of additional disturbance. In high risk management zones, the retention requirement is fixed at 75 percent. In medium risk management zones, a variable additional retention requirement is applied based on localised impacts, expected to be approximately 65 percent on average of a local landscape area.

The risk assessment framework is designed to consider both high and extreme severity fire impacts from the 2019/20 wildfires (using version 3 of DPIE-EES' Fire Extent and Severity Mapping (FESM)) and the recovery of those high and extreme impacts since fire (using the post-fire spectral recovery index developed by the Department of Planning, Industry and Environment's Environment, Energy and Science group (DPIE-EES) and the Department of Primary Industries Forest Science team (DPI Forest Science)). This approach draws on the best available data and science for decision making.

[1] Standard Coastal IFOA prescriptions reflect an outcomes-based approach to regulation, with a multi-scale landscape approach to establishing habitat and native fauna protections. The Coastal IFOA incorporates several aspects of best-practice forestry management, including: permanent exclusion zones, retention of important feed and habitat resources within the harvesting footprint; harvesting limits and regimes that distribute short-term impacts in space and time; and settings to minimise impacts on soil and water quality from roading, harvesting and other activities.

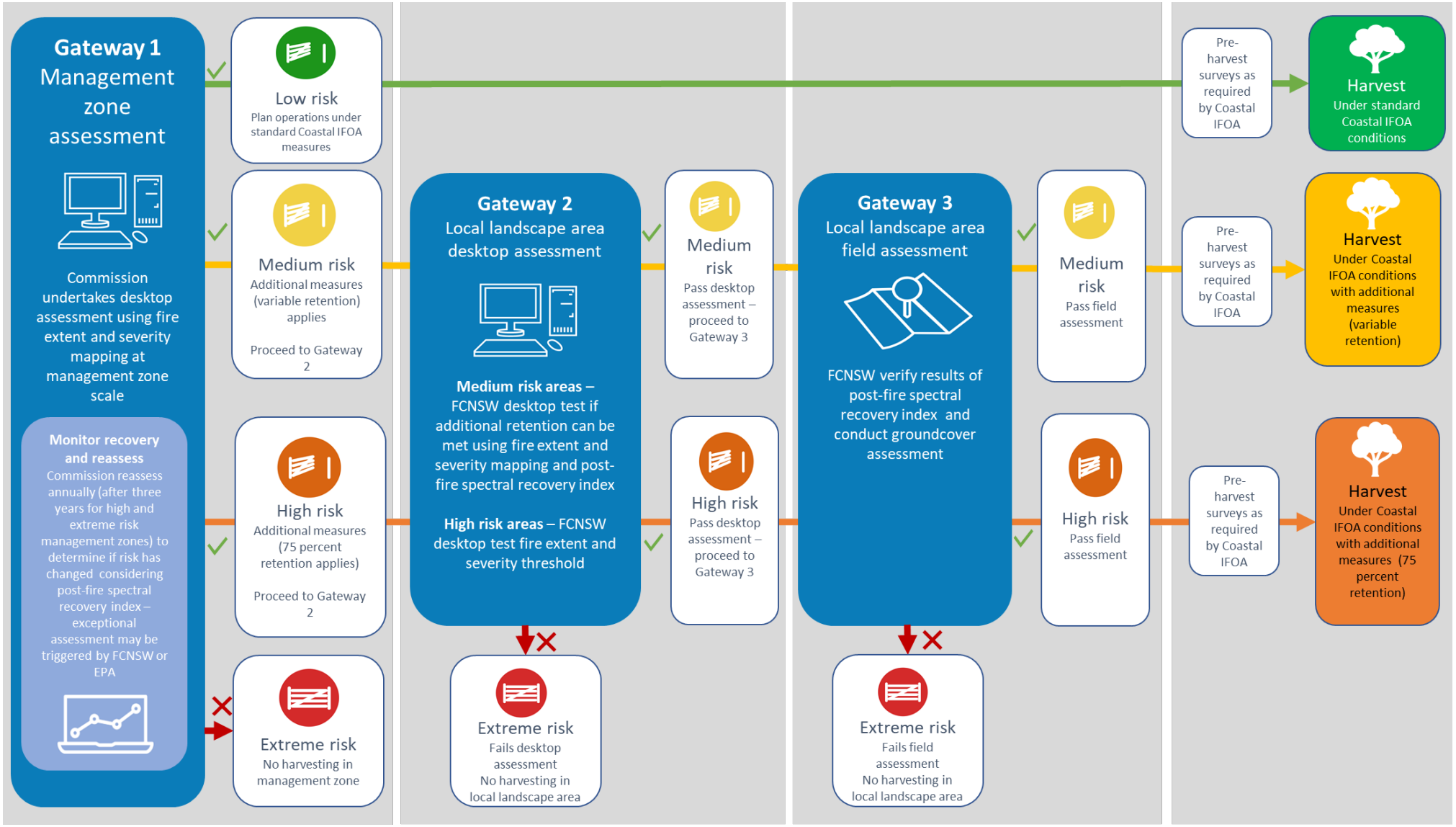

Figure 1: Risk and evidence-based framework used to determine pathways

Results of Gateway 1 assessment and recommended pathways

The Commission has undertaken the management zone-scale assessment (Gateway 1) using the best available data. **Table 1** shows the risk rating and recommended Gateway 1 pathway for each management zone and **Figure 2 s**hows the location of management zones and risk ratings.

Table 1: Summary of assessment results for the Commission's Gateway 1 assessment

Assessment result	Management zones
Low risk – Harvesting should be allowed under standard Coastal IFOA prescriptions	**Seven management zones:** ▪ Bulahdelah ▪ Chichester ▪ Tenterfield ▪ Urbenville ▪ Urunga ▪ Walcha-Nundle ▪ Wingham
Medium risk – Pending gateway 2 and 3 assessments, harvesting should be allowed under standard Coastal IFOA prescriptions with additional measures, including temporary refuge based on a variable retention requirement in local landscape areas	**Eleven management zones:** ▪ Casino ▪ Coffs Harbour ▪ Coopernook ▪ Grafton ▪ Kempsey ▪ Kendall ▪ Morisset ▪ Queanbeyan ▪ Styx River ▪ Tumut ▪ Wauchope
High risk – Pending gateway 2 and 3 assessments, harvesting should be allowed under standard Coastal IFOA prescriptions with additional measures, including temporary refuge based on a fixed retention requirement of 75 percent in local landscape areas	**Six management zones:** ▪ Badja ▪ Bago-Maragle ▪ Batemans Bay ▪ Dorrigo ▪ Eden ▪ Glen Innes
Extreme risk – Harvesting should be suspended for three years from February 2020	**Three management zones:** ▪ Narooma ▪ Nowra ▪ Taree

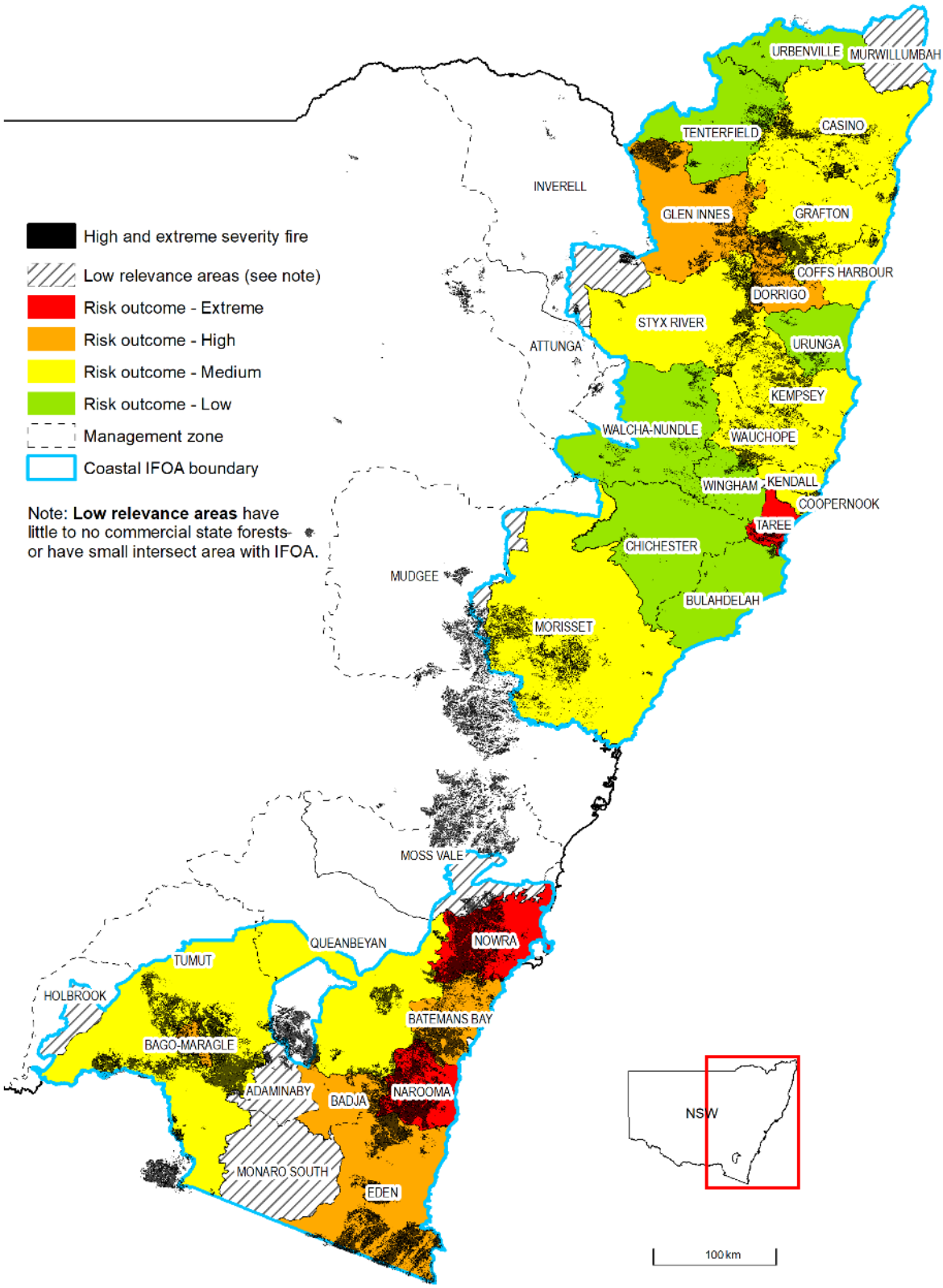

Figure 2: Risk assessment results by management zone

Significant short-term reduction in wood supply is likely on the south coast under the pathways, with smaller impacts on the north coast

The 2019/20 wildfires resulted in reduced wood supply, particularly on the south coast. For this review, FCNSW with oversight by the Commission analysed the potential wood availability and wood supply under the recommended pathways and risk mitigations, based on a scenario of progressive recovery.

FCNSW advised that the potential impact of the recommendations on timber supply cannot currently be estimated with a high level of confidence. A more detailed understanding on how gateways 2 and 3 are practically applied on-ground is needed to provide a more accurate estimate of short- to medium-term impacts on wood supply. Noting these limitations, the analysis indicates that significant short-term impacts are likely on the south coast, with smaller impacts on the north coast.[2]

Impacts were most severe in the South Coast subregion, where there may be up to an 80-90 percent reduction in planned wood supply volume based on the Commission's recommended pathways and risk mitigations. In the Eden subregion, risk mitigations are expected to reduce available wood supply volume by 40 percent. These impacts, while not as large as in the South Coast subregion, are still significant. In the Tumut subregion there is an estimated reduction in supply of approximately 35 percent of wood supply agreement volume. Across the north coast subregions, wood supply may be reduced by 10-20 percent under the recommended pathways and risk mitigations.

In the north coast and Eden subregions, FCNSW considers that impacts on the current operational plans could be mitigated over time by additional planning of alternative areas where harvesting can occur. However, this will require significant planning resources.

There are likely to be significant short-term jobs at risk in south coast subregions, with mill viability at risk. Jobs at risk are expected to be lower on the north coast.

Based on advice from FCNSW, reductions in wood supply from the 2019/20 wildfires has already had flow-on impacts to the forest industry in the form of reductions in work shifts and some redundancies in regions where wood supply was substantially reduced. 74 jobs were reported to have been stood down at March 2021.

The Commission analysed potential short-term impacts on the forest industry based on the potential reductions in wood supply from applying the outcomes of the risk assessment and mitigations recommended in this report. However, there were limited data on the forest industry, and no NSW-specific data on the correlation between wood volumes and employment. Estimates based on direct ratios of wood supply to employment also do not consider operating needs of mills, which require enough throughput to remain competitive. Further, under the terms of reference the Commission was not able to consult with the forestry sector or forest industry, which also impacts the accuracy of estimates.

The Commission notes that there would have been continued significant risks to jobs from the impacts of the wildfires themselves, as well as from the continued application of SSOCs and FCNSW voluntary measures.

[2] For the purposes of this review, the term 'south coast' refers to the general Coastal IFOA area on the south coast of NSW. This area has three subregions: South Coast, Eden and Tumut. The term 'north coast' refers to the general Coastal IFOA area on the north coast of NSW. This area has two subregions: Upper North East and Lower North East.

Noting the limitations, analysis using comparable interstate data indicates there is likely to be a significant risk to jobs in south coast subregions at least in the short term and potentially longer if mills are no longer viable at reduced supply levels. It is possible that some parts of the industry will not be viable to operate at the forecast supply levels. Estimated reduced wood supply volumes place the Nowra and Narooma sawmills at risk. Reductions in wood supply would also likely lead to lower operating levels for the existing mill and the mill currently under construction in Eden. The significantly reduced operating levels may make the mills non-viable. It is estimated that over half the forestry jobs in the south coast and Eden subregions would be affected in the short term (next 18 months) and potentially in the medium term. This warrants immediate further analysis and engagement with industry.

North coast subregions could see a relatively smaller amount of jobs at risk. The location of impact is difficult to determine and could be driven by several factors, including the potential to supplement supply from private native forestry, the capacity to redirect supply-demand imbalances and capacity of industry to use less preferred timber species.

The terms of reference did not ask the Commission to advise on recommended actions to address or mitigate potential impacts on industry. It is also not practical to do this given the uncertainties in the current analysis described above. Industry should be consulted to enable NSW Government to quantify the impacts of the measures proposed in the recommendations in this report.

The risk assessment framework allows for long-term management of risks to forests

The risk assessment framework is not a one-off process. Forests are dynamic ecosystems. There will continue to be variable recovery and future fires of varying severity and extent. The NSW Government and industry need to adapt to changing risks, including climate change. The risk assessment framework and pathways provide a mechanism to reassess risk and should be applied after the designated reassessment periods outlined in the framework.

There is already evidence of vegetation recovery in some areas due to above average rainfall in late 2020 and early 2021. If these regions continue to recover, reassessment would allow them to be given a lower risk rating once nominated thresholds for recovery are reached and timing for reassessment is met. Similarly, the reassessment also allows for risk ratings to be increased in the event of further large-scale forest impacts, such as future fires. This is important given predicted changes to climate will continue to challenge the health and condition of NSW forest ecosystems.

A new condition and protocol should be included in the Coastal IFOA to give effect to the pathways

The recommended pathways and risk assessment framework have been developed in response to a *force majeure* event: the 2019/20 wildfires were an unforeseen circumstance that would prevent FCNSW from fulfilling its obligations under the Coastal IFOA to meet the Coastal IFOA objectives and outcomes. There is currently no condition in the Coastal IFOA that enables broad scale changes to conditions to be efficiently implemented in the event of a large-scale fire, such as the 2019/20 wildfires.

To give effect to the pathways, a new condition and protocol should be developed and included in the Coastal IFOA. The Commission considers that this is the most effective way to ensure the NSW Government can provide effective regulatory responses to *force majeure* events in the future.

Alternative approaches to implementing the framework and pathways include continuing to apply SSOCs under Condition 23.4 of the Coastal IFOA or through a voluntary arrangement with FCNSW, noting the Environment Protection Authority (EPA) has no authority to regulate voluntary arrangements. However, the Commission considers these approaches would be less efficient, transparent, and potentially less effective (in the case of SSOCs). They would also be harder to apply consistently, enforce and regulate.

Interim arrangements should be implemented ahead of a new condition and protocol being finalised

Agencies advised that a new condition and protocol will likely take approximately 12 months to develop, conduct public consultation and submit to Ministers to consider and approve. However, there is an urgent need to provide greater certainty to the timber industry and the regional communities dependent on this industry and to provide greater environmental protections over what the Coastal IFOA currently provides for. Further, in the absence of agreed SSOCs, there is a need for clarity on how the NSW Government is overseeing FCNSW fulfilling its responsibilities in ecologically sustainable forest management (ESFM) in response to the wildfires. In addition, it is essential to test and understand the practical implications associated with implementing gateways 2 and 3 in the risk assessment.

To address these concerns, the Commission recommends the following interim arrangements be adopted while the NSW Government fast-tracks the recommended condition and protocol. These include that:

- FCNSW can commence new forestry operations under standard Coastal IFOA prescriptions in management zones classified by the Commission as low risk (and continue any existing forestry operations in low risk areas)
- jointly under Section 69R of the *Forestry Act 2012*, the two Ministers suspend existing, planned or new forestry operations in management zones classified by the Commission as extreme risk until a new condition and protocol is adopted[3] (existing operations should cease as soon as operationally practical but no longer than three months)
- the NSW Government request in writing that FCNSW:
    - continues with existing forestry operations under SSOCs or the Coastal IFOA with FCNSW's additional supplementary measures in management zones classified by the Commission as medium or high risk, but harvesting in these operations must cease within six months, after which interim arrangements must be voluntarily adopted (described in the following point)
    - for all other forestry operations, adopt on a voluntary basis the risk assessment process, including fieldwork, and additional measures for planned or new forestry operations in management zones classified as medium and high risk, and apply until a new condition and protocol is adopted
- the Commission oversees the interim arrangements in close collaboration with FCNSW and EPA and provides any further advice to the NSW Government on the recommended condition and protocol before finalising.

[3] The Commission notes that under obligations intended to be legally enforceable in the NSW Regional Forest Agreements, NSW is required to advise the Commonwealth within 14 days of a termination, suspension or revocation of an integrated forestry operations approval that applies in a Regional Forest Agreement area.

The framework should be adaptively managed, and a stronger evidence base established for long-term forest management

The Commission is confident that the proposed framework is fit-for-purpose and has built in several safeguards – including multi-scale risk assessments and field tests – to reduce the risk of errors or perverse assessment outcomes.

However, like most management processes, uncertainties will always remain, such as in the setting of risk thresholds. As such, it is critical that an adaptive management approach is adopted, with mechanisms allowing for regular review and improvement of the framework as lessons are learned through its implementation. This could be efficiently facilitated through the existing Coastal IFOA annual health check process overseen by the NSW Forest Monitoring Steering Committee.

The NSW Government's existing Forest Monitoring and Improvement Program will lead and coordinate monitoring, evaluation and research for improved forest management on public and private land. However, there are additional monitoring and research needs required to support the implementation of the framework and inform policies and responses to future large-scale fire events.

While decision making in this area will always rely on judgement and expert advice to some extent, the NSW Government should invest in building the evidence and tools to support future data-driven decision making. This will help reduce uncertainty and increase confidence in 'what to do next' when future fires impact forests and the forestry sector.

The results of climate and wildfire modelling indicate that these drought and fire conditions will happen again in the future. Ensuring the NSW Government has the best empirical evidence regarding the impacts of the full range of management prescriptions will allow faster, more targeted, and more effective responses to future wildfires. This will save money, protect jobs, and better protect forest values, including biodiversity.

Agencies require additional resources to implement the pathways

Implementing the pathways will require additional resources, including to accelerate the development of datasets and undertake desktop and field assessments for the gateways. The development of a new condition and protocol will also require legal and policy resources. While the current Forest Monitoring and Improvement Program will support implementation of the pathways if adopted, the scope and scale of some of this work will need to be expanded, including targeted, experimental research to understand if and how forestry can occur in future post-fire landscapes.

Recommendations

1 The NSW Government should adopt the Gateway 1 pathways presented in **Table 1** and **Figure 2** in this report, to:

1.1 allow for harvesting under standard Coastal IFOA prescriptions in the following **seven low risk management zones**: Bulahdelah, Chichester, Tenterfield, Urbenville, Urunga, Walcha-Nundle and Wingham

1.2 allow for harvesting under standard Coastal IFOA prescriptions with additional measures (as described **Table 16**), including temporary refuges based on a variable retention requirement in local landscape areas in the **following eleven medium risk management zones**: Casino, Coffs Harbour, Coopernook, Grafton, Kempsey, Kendall, Morisset, Queanbeyan, Styx River, Tumut and Wauchope

1.3 allow for harvesting under standard Coastal IFOA prescriptions with additional measures (as described **Table 16**), including temporary refuges based on a fixed retention requirement of 75 percent in local landscape areas in the following **six high risk management zones**: Badja, Bago-Maragle, Batemans Bay, Dorrigo, Eden and Glen Innes

1.4 temporarily suspend harvesting for a minimum of three years (from February 2020) in the following **three extreme risk management zones**: Narooma, Nowra and Taree.

2 The NSW Government should adopt the Commission's risk assessment framework used to determine the pathways in Recommendation 1 (as presented in **Chapter 5**) and apply it at the reassessment intervals outlined in the framework until all management zones have returned to standard Coastal IFOA prescriptions (low risk). The NSW Government should request the Commission to undertake the annual reviews, including Gateway 1 assessments.

3 To give effect to the pathways and risk assessment:

3.1 the NSW Government should amend the Coastal IFOA to include a new *force majeure* condition and associated protocol that includes the risk assessment process (**Chapter 5**) and additional measures set out in **Table 16**

3.2 as required by the *Forestry Act 2012*, the NSW Government should include in the development of the new condition public consultation and joint approval by the Deputy Premier/Minister for Regional NSW and Minister for Energy and Environment[4]

3.3 the Chief Executive Officer of the EPA and the Director General of DPI should jointly approve the new protocol

3.4 the EPA must collaborate with the FCNSW in developing the new protocol, and on any subsequent amendments

3.5 the NSW Government should accelerate improvement of DPIE-EES' recovery index in consultation with FCNSW, including a large-scale, funded, scientific field sampling strategy across the Coastal IFOA region and request the Commission to oversee this work through the Forest Monitoring and Improvement Program. The

[4] The *Forestry Act 2012* requires joint approval from the Minister for the Environment and Minister for Lands and Forestry. The Commission has adopted the Ministers' current portfolio titles throughout this report.

post-fire spectral recovery index should be updated in January each year based on new satellite imagery.

4 The NSW Government should adopt the interim implementation arrangements outlined in **Section 4.2** while the recommended condition and protocol is developed to provide additional time to test and understand the practical implications associated with implementing gateways 2 and 3 in the risk assessment.

5 The NSW Government should provide FCNSW, EPA, DPIE-EES and the Commission with additional resources for planning and field-testing to implement the recommended framework and pathways.

6 The NSW Government should initiate a rapid assessment of forestry industry size, viability, and resilience to changes in wood supply for south coast subregions in full consultation with industry.

7 To ensure the risk framework is responsive to new data and events, the NSW Government requests the NSW Forest Monitoring Steering Committee to:

7.1 regularly review and improve the risk assessment framework under its oversight role and annual health checks for the Coastal IFOA monitoring program including public reporting

7.2 recommend priority research and monitoring (**Section 4.5**) for further funding.

8 To ensure that future forestry in a changing climate is sustainable and reflects best practice, the NSW Government should:

8.1 ensure the risks of achieving Coastal IFOA outcomes and objectives under predicted change in fire regimes and drought are effectively considered during the scheduled five-yearly Coastal IFOA review, in consultation with the community

8.2 fund FCNSW to accelerate its sustainable yield modelling improvement program to incorporate projected climatic and fire regimes and post-fire mortality and growth assumptions. This work to include a reference group, including relevant independent experts, the EPA, DPIE-EES, DPI Forestry and the Commission

8.3 consider how it can best support regional employment and multi-use forests under different predicted climatic and fire scenarios

8.4 invest in landscape-scale research on forestry and forest management, including ecological recovery and regeneration in the south coast. This could span two management zones assessed as high and extreme risk with similar forest types to ensure a full suite of fire severity impacts are included.

9 The NSW Government should increase investment in large-scale, regionally coordinated pest and weed control on state forests to address risks from incursion and predation.

1 Introduction

The 2019/20 wildfires burnt 4.8 million hectares of land in NSW, including just over 64 percent (around 0.7 million hectares) of the native state forest estate.[5] The wildfires significantly impacted forest ecosystems, including native flora and fauna, soil and water (detailed evidence of impacts on forest ecosystems is outlined in **Chapter 6**).

The wildfires also extensively impacted communities, with 26 fatalities, 2,476 homes destroyed, loss of other infrastructure and business assets, ongoing physical and mental health impacts, and financial hardship.[6] Within state forests and national parks, loss of visitor infrastructure, road and bridge damage, and other hazards in fire-affected forests resulted in the temporary closure of forests to the public, with flow-on impacts for local community groups and commercial operators, particularly in the South Coast and Eden subregions.[7] FCNSW estimated the cost of reinstating damaged assets to reopen state forests for nature-based tourism and recreation in the order of $1.8 million excluding labour and specialist contractors.

Aboriginal people were disproportionately affected, with many wildfire-affected areas in NSW having Aboriginal populations greater than 20 percent of total population, including the Grafton, Eurobodalla Hinterland, Armidale and the Kempsey regions.[8] Aboriginal peoples' experience of fire crises is vastly different to non-Indigenous peoples. Aboriginal peoples' relationships to Country, culture and community are not only interconnected, they are intrinsically linked to their identity and role as custodians. This means that when any of these foundations are impacted by a fire or other disaster, Aboriginal peoples experience unique trauma[9] such as loss of native food sources, burning of ancient scarred trees and destruction of ancestral and totemic plants and animals.[10]

The native forest timber industry has also been severely impacted due to a reduced supply of timber. Forestry operations in coastal NSW usually occur under the Coastal IFOA. There are 5.2 million hectares of public native forest within the Coastal IFOA region, including state forests, national parks, and other Crown land,[11] of which nearly 3.7 million hectares was affected by the 2019/20 wildfires.

---

5 Based on latest statistics from DPIE's fire extent and severity mapping (DPIE (2020) *Supporting fire management with the Fire Extent and Severity Maps*. Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/fire-extent-and-severity-mapping-fact-sheet-200068.pdf).

6 NSW Government (2020) *Final Report of the NSW Bushfire Inquiry July 2020.* Available at: https://www.nsw.gov.au/nsw-government/projects-and-initiatives/nsw-bushfire-inquiry.

7 For the purposes of this review, the term 'south coast' refers to the general Coastal IFOA area on the south coast of NSW. This area has three subregions: South Coast, Eden and Tumut. The term 'north coast' refers to the general Coastal IFOA area on the north coast of NSW. This area has two subregions: Upper North East and Lower North East.

8 Whittaker, J. and Bedward, M. (2020) Demographic characteristics of populations affected by the 2019/2020 bushfires in NSW. In NSW Bushfire Risk Management Research Hub Reports to the NSW Bushfire Inquiry 2020 – Theme 3A- People and Property Impacts.

9 Williamson, B. and Quinn, P. (2021) Unwelcoming and reluctant to help: bushfire recovery hasn't considered Aboriginal culture — but things are finally starting to change. *The Conversation*, February 24. Available at: https://theconversation.com/unwelcoming-and-reluctant-to-help-bushfire-recovery-hasnt-considered-aboriginal-culture-but-things-are-finally-starting-to-change-154954.

10 Williamson, B., Weir, J. and Cavanagh, V. (2020) Strength from perpetual grief: how Aboriginal people experience the bushfire crisis. *The Conversation*, January 10. Available at: https://theconversation.com/strength-from-perpetual-grief-how-aboriginal-people-experience-the-bushfire-crisis-129448.

11 Slade, C. and Law, B. (2017) 'The other half of the coastal State Forest Estate in New South Wales; the value of informal forest reserves for conservation', *Australian Zoologist,* 39(2): 359-370.

The Coastal IFOA prescriptions apply to native forests on state forests and other Crown-timber land[12] accounting for 17 percent of total native forest within the Coastal IFOA region.[13] Approximately 2 percent of the broader native forest within the Coastal IFOA region is harvested in any year.[14] Over 0.7 million hectares of native state forest across the Coastal IFOA region was affected by the fires.

The NSW Government adopted the Coastal IFOA in 2018 on the basis that it reflected best practice forest management, particularly in its outcomes-based approach to regulation and its multi-scale landscape approach that enhanced protections for habitat and native fauna. It also built on the previous IFOA prescriptions and complemented the existing conservation reserve system. Specifically, the Coastal IFOA incorporates several aspects of best-practice forestry management, including:

- permanent exclusion zones to protect sensitive areas – for example, mapped rainforest and old growth, ridge, and headwater habitats and wildlife habitat and tree retention clumps. On average, just over 50 percent of state forests are permanently excluded from harvesting in these areas
- retention of important feed and habitat resources within the harvesting footprint – for example, wildlife habitat and tree retention clumps permanently exclude from harvesting up to an additional 13 percent of the net harvestable area
- harvesting limits and regimes that distribute short-term impacts in space and time – for example, return periods and adjacency rules for different harvesting types that limit the area and location of harvesting in state forests in any given year
- settings that minimise impacts on soil and water quality from roading, harvesting and other activities – for example, riparian buffers around streams to protect water quality and provide important habitat for some forest-dependent species.

In adopting the approval, the NSW Government had sufficient confidence that native forests could withstand the short-term impacts of harvesting and that adequate safeguards were in place to protect environmental values over the long term. This decision accepted that there would be localised, short-term impacts at the site scale from forestry operations.

However, the Coastal IFOA was not designed to mitigate the risks of harvesting in a severely fire-affected landscape resulting from an unprecedented event like the 2019/20 wildfires.[15] This meant additional measures were required to manage unanticipated risks associated with the extent and severity of the fires.[16] As a result, forestry operations have ceased in many areas. Several operations are now occurring in north coast state forests under the Coastal IFOA

12 EPA (2018) *Coastal Integrated Forestry Operations Approval – Conditions*. Available at: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/forestagreements/18p1177-coastal-ifoa-conditions.pdf.

13 Slade, C. and Law, B. (2017) 'The other half of the coastal State Forest Estate in New South Wales; the value of informal forest reserves for conservation', *Australian Zoologist,* 39(2): 359-370.

14 FCNSW (2020) *2019-20 Wildfires – Environmental impacts and implications for timber harvesting in NSW state forests. An assessment of the impact of the 2019-20 fire season on biodiversity, soil and water values and implications for managing ongoing timber harvesting operations in native State forests.*

15 EPA (2021) *Bushfire-affected forestry operations*. Available at: https://www.epa.nsw.gov.au/your-environment/native-forestry/bushfire-affected-forestry-operations.

16 EPA (2021) *Bushfire-affected forestry operations*. Available at: https://www.epa.nsw.gov.au/your-environment/native-forestry/bushfire-affected-forestry-operations.

without additional mitigations. In other areas, forestry has continued in a limited fashion since early 2020 under SSOCs negotiated by the EPA and FCNSW.[17]

These SSOCs were issued because FCNSW considered it could not meet the expected 70 percent groundcover threshold in the Coastal IFOA, as well as where it was not considered safe to undertake prescribed field surveys in a normal manner in the immediate aftermath of the wildfires.[18] The SSOCs contain prescriptions for soil and water quality, and biodiversity protection. This approach is intended to be temporary while the forests recover. In February 2021, FCNSW advised the EPA that it intended to recommence forestry operations under the Coastal IFOA with additional voluntary measures in south coast state forests.[19] As at 31 May 2021, FCNSW advised it had harvested 205 hectares across compartments in Bago, Mogo, Nadgee and Yambulla state forests under these voluntary measures.[20]

1.1 What the Commission was asked to do

The severity of impacts and uncertainty around forest recovery have made it unclear when, where and how it will be practicable to commence forestry operations under standard Coastal IFOA prescriptions. FCNSW and the timber industry need more certainty to understand if and when relevant wood supply agreements are likely to be fully met and the short- to long-term impacts on regional businesses and job security. Communities also need confidence that the potential cumulative impacts of forestry operations in fire-affected landscapes will not impact environmental values.

Through a terms of reference, the Deputy Premier and Minister for Regional NSW, Industry and Trade, the Minister for Energy and Environment, and the Minister for Planning and Public Spaces have asked the Commission to provide independent, evidence-based advice on pathways back to FCNSW operating under standard Coastal IFOA prescriptions.

The terms of reference (**Appendix 1**) for this advice ask the Commission to:

1 review the available scientific evidence on the environmental impacts of forestry operations under the standard Coastal IFOA prescriptions and the SSOCs in areas affected by the 2019-20 wildfires, and identify any knowledge gaps or absence of robust scientific evidence. The Commission may engage independent experts to inform its advice.

2 make specific recommendations on pathways back to FCNSW operating under standard Coastal IFOA prescriptions in forests both where SSOCs are in place and elsewhere in fire-affected forests across NSW. This may include consideration of:

- severity and extent of the fire in relation to particular areas or ecological communities

17 EPA (2021) *Bushfire-affected forestry operations*. Available at: https://www.epa.nsw.gov.au/your-environment/native-forestry/bushfire-affected-forestry-operations.

18 There are currently 66 compartments across 12 state forests operating under SSOCs (EPA (2020) *Bushfire-affected forestry operations*. Available at: https://www.epa.nsw.gov.au/your-environment/native-forestry/bushfire-affected-forestry-operations).

19 For the purposes of this review, the term 'south coast' refers to the general Coastal IFOA area on the south coast of NSW. This area has three subregions: South Coast, Eden and Tumut. The term 'north coast' refers to the general Coastal IFOA area on the north coast of NSW. This area has two subregions: Upper North East and Lower North East.

20 The management zones for these state forests are: Bago State Forest (Bago-Maragle), Mogo State Forest (Batemans Bay), Nadge State Forest and Yambulla (Eden).

- forest recovery criteria
- time since the fire
- staging or prioritising recommencement of standard Coastal IFOA prescriptions to minimise impacts to the environment.

3 recommend, using the best available scientific evidence, best practice approaches to manage forestry operations in fire-affected forests to satisfy the purposes of Part 5B of the *Forestry Act 2012* and the objectives and outcomes specified in the Coastal IFOA, including having regard to the Commission's views on the recovery of the fire-affected forests over time following bushfires.

The terms of reference also ask that, where any of the Commission's recommendations may have an impact on FCNSW's ability to meet wood supply, the Commission consider the implications of such recommendations and advise on their impact on wood supply and the timber industry.

The terms of reference states the review will inform the responsible Ministers on a recommended way to give effect to the advice of the Commission to manage forestry operations in fire-affected forests following the 2019- 20 wildfires.

1.2 The Commission's approach

In line with the terms of reference, the Commission:

- has engaged a panel of independent experts to inform its advice (see **Box 1**)
- has engaged other scientific experts to provide specific subject matter analysis – for example, researchers at the University of Melbourne and the University of Wollongong
- is consulting with agencies, including FCNSW, the EPA, DPIE-EES and the Department of Regional NSW (DRNSW) (DPI Forestry)
- is sharing relevant information with FCNSW, EPA, DPIE-EES and DRNSW, including preliminary findings and recommendations for review.

In developing the pathways, the Commission is considering:

- best available scientific evidence
- spatial and temporal variability in wildfire impacts and recovery
- the existing management framework for forests in NSW
- the principles of ESFM, including the precautionary principle (**Box 2**)
- broader landscape-scale impacts of the wildfires on other forest tenures (for example, national parks)
- proposals put forward by agencies for forestry operations in fire-affected landscapes
- cumulative impacts of multiple disturbances and climate change, including the potential risk of further large-scale wildfire complexes in the future
- a risk-based approach to assess pathway options for forestry operations in fire-affected landscapes

- the Coastal IFOA objectives[21] and outcomes,[22] including outcomes-based approaches to manage forestry operations[23]
- embedding key elements of pathway implementation within the Coastal IFOA monitoring program and the Forest Monitoring and Improvement Program.

Box 1: Independent expert advisors

Professor Patrick Baker – School of Ecosystem and Forest Sciences, the University of Melbourne, Charles Bullard Fellow in forest science at Harvard University, and former Australian Research Council Future Fellow

Associate Professor Tina Bell – Associate Professor in Fire Ecology, the University of Sydney

Associate Professor Gary Sheridan – School of Ecosystem and Forest Sciences, the University of Melbourne, Forest Hydrology Research Group

Dr Sarah Munks – Consultant scientist and Adjunct Senior Researcher, School of Natural Sciences, University of Tasmania, and former Biodiversity Manager, Research and Advisory Section, Forest Practices Authority Tasmania.

Box 2: The precautionary principle

The precautionary principle is one of the key components of ecologically sustainable development as defined in the *Protection of the Environment Administration Act 1991*. The principle states that, if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.[24] In the application of the precautionary principle, decisions should be guided by:

- careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment
- an assessment of the risk-weighted consequences of various options.[25]

1.3 This report

This report presents the Commission's final advice on the terms of reference. The report is in three parts:

- **Part 1 – The pathways and implications** – this part outlines the results of the management zone-scale risk assessment and recommended pathways back to FCNSW operating under standard Coastal IFOA prescriptions while managing risks to environmental values. It also outlines the potential impacts on short to medium term wood supply and implications for industry. The Commission has also made recommendations on giving effect to the pathways.

21 The Coastal IFOA objectives have been aligned to four risk categories which are to: (i) maintain the persistence of species (biodiversity) (ii) protect aquatic habitat (iii) to ensure adequate forest regeneration for ongoing timber production. **Appendix 5** lists the Coastal IFOA outcomes aligned to these categories.

22 The Coastal IFOA has 31 outcome statements.

23 An outcomes-based approach relies on the forest manager making decisions on actions to meet regulatory objectives, with greater flexibility compared with the previous prescriptive code.

24 Section 6 of the *Protection of the Environment Administration Act 1991*.

25 Section 6 of the *Protection of the Environment Administration Act 1991*.

- **Part 2 – The framework used to develop the pathways** – this part outlines the Commission's approach to developing the pathways based on a risk and evidence-based framework.
- **Part 3 – Wildfire and forestry impacts** – this part outlines the analyses used to inform the development of the pathways. This includes analysis required by the terms of reference, including on the impacts of the 2019/20 wildfires, evidence of cumulative impacts of wildfire and forestry and the implications of this for achieving Coastal IFOA objectives and outcomes.

Part 1 – The pathways and implications

2 Recommended pathways

2.1 Developing the pathways

The Commission developed a data-driven risk assessment framework using best available information and expert advice to recommend pathways back to FCNSW operating under standard Coastal IFOA prescriptions.

Adopting this risk assessment framework and pathways will provide a repeatable and transparent approach for agencies to manage forestry operations, while providing for the recovery, protection and persistence of environmental values following large-scale wildfires. It will also provide greater certainty around potential wood supply impacts over time for industry and increase transparency and accountability in current arrangements (impacts are discussed in **Chapter 3**).

Figure 3 gives an overview of the assessment framework and pathways. A more detailed outline of this process is included in **Part 2** of this report. Broadly, the framework has three gateways at which different assessments are undertaken, with risk ratings assigned to determine next steps:

- **Gateway 1** applies a desktop risk assessment at the management zone scale. Four risk ratings are assigned at this stage:
  - **Low risk** - Forestry operations could commence in an area under standard Coastal IFOA prescriptions.[26]
  - **Medium risk** - Forestry operations could commence under Coastal IFOA prescriptions with additional measures to provide temporary refuge at variable levels and water quality protections in addition to standard Coastal IFOA protections. Subject to the outcomes of the Gateway 2 and 3 assessments, the additional measures applied in local landscape areas include variable additional retentions. These additional retentions are retained in temporary refuges located primarily in unburnt and lightly burnt[27] forest to supplement the existing harvesting exclusions that remain severely impacted by fire. Further detail on additional measures applied in medium risk management zones is provided in **Table 16**.
  - **High risk** - Forestry operations could commence under Coastal IFOA prescriptions with additional measures to provide temporary refuge at a fixed requirement. Subject to the outcomes of the gateway 2 and 3 assessments, local landscape areas in high risk areas are subject to a fixed 75 percent retention. This must be achieved through retaining Coastal IFOA prescriptions, unburnt and lightly burnt habitat refuge and adjacent burnt areas. This measure allows for regeneration practices to be applied that are suitable for the forest type but heavily restricts these activities to focus on regeneration for future ecological and

[26] Standard Coastal IFOA prescriptions reflect an outcomes-based approach to regulation, with a multi-scale landscape approach to establishing habitat and native fauna protections. The Coastal IFOA incorporates several aspects of best-practice forestry management, including: permanent exclusion zones, retention of important feed and habitat resources within the harvesting footprint; harvesting limits and regimes that distribute short-term impacts in space and time; and settings to minimise impacts on soil and water quality from roading, harvesting and other activities.

[27] Unburnt and lightly burnt forest refers to the FESM severity classes including unburnt, low severity and moderate severity, unless in forest types dominated by obligate seeders (such as alpine ash (*E. delegatensis*)) where it refers to FESM severity class including unburnt and low severity.

timber supply outcomes. A reassessment in high risk management zones is not undertaken for a period of three years following the fire,[28] a period intended to minimise further disturbance while the forest ecosystem and forest-dependent species recover. For example, this will allow many resprouting species time to flower post-fires.[29] Further details on additional measures applied in high risk management zones are provided in **Table 16**.

- **Extreme risk –** Forestry operations should be temporarily suspended for three years from the time of the fires with reassessment after this period. As described above, this suspension will allow time for recovery of forest ecosystems and forest dependent species without further disturbance from forestry operations. This is a precautionary measure to allow for forest ecosystem recovery to progress in this management zone.

- **Gateway 2** applies to local landscape areas within management zones that received a medium or high risk rating in Gateway 1. This step involves a desktop assessment to test if additional measures for medium risk areas can be met at the operational scale. For high risk zones the gateway tests if the local landscape area has met a burnt area threshold, with the intent to direct harvesting away from less burnt forests to protect these as refuges to support recovery. At this gateway, local landscape areas may continue to Gateway 3 if they pass the assessment or move to an extreme risk rating and pathway if they do not pass.
- **Gateway 3** applies to local landscape areas within management zones that received a medium or high risk rating that have passed Gateway 2. This step involves a field assessment at the local landscape area scale before harvesting can proceed to verify the recovery status of the forest, the presence of suitable retention habitat and to ensure adequate groundcover. At this gateway, local landscape areas may proceed to pre-harvest planning and surveys commensurate with the allocated risk pathway if they pass the assessment or move to an extreme risk rating if they do not pass.

There is evidence that harvesting in a fire-affected area can have a cumulative impact. However, the evidence base is not comprehensive or specific to fire-affected landscapes in NSW (see **Chapter 7**). As such, consistent with the precautionary principle, the risk assessment framework and pathways centre on careful evaluation and conservative decision-making where risks have a higher degree of uncertainty. Where NSW-specific information is available on the cumulative impacts, this has been considered. For example, the flowering patterns of eucalypts in northern NSW following disturbance[30] was considered when proposing time until reassessment in high and extreme risk management zones. Further, no specific measures were proposed for managing coarse woody debris in post-fire harvesting operations, as harvesting generates a pulse of coarse woody debris.[31]

---

28 The three-year period following the 2019/20 wildfires commences as at February 2020.

29 See for example: Burrows, N.D., Wardell-Johnson, G., and Ward, B. (2008) 'Post-fire juvenile period of plants in south-west Australia forests and implications for fire management'. *Journal of the Royal Society of Western Australia*, 91:163-174; Law, B., Mackowski, C., Shoer, L., and Tweedie, T. (2000) 'Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales'. *Austral Ecology*, 25:160–178.

30 Law, B. Mackowski, C. Shoer, L. and Tweedie, T. (2000) 'Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales'. *Austral Ecology*, 25: 160–178.

31 Stares, M.G., Collins, L., Law, B. and French, K. (2018) 'Long-Term Effect of Prescribed Burning Regimes and Logging on Coarse Woody Debris in South-Eastern Australia.' *Forests*, 9:242.

The Commission has adopted conservative risk thresholds and has also included field testing to confirm the results of desktop analysis. While field testing should remain an important element of the framework, as the understanding of the impact of forestry in fire-affected landscapes grows through further monitoring and research, the thresholds for risk assessment should be reviewed and, if appropriate, may be refined for future reassessment.

This review found there is currently no agreed best practice in NSW for managing forestry operations in severely fire-affected forests and no accepted body of evidence on how to manage severely fire-affected native forests in NSW as they recover. However, in line with the terms of reference, the pathways and risk assessment framework (including additional measures) have been informed by best practice approaches to forest management.[32]

The Commission identified best practice approaches, aligned with the principles of ESFM, using best available scientific evidence (including local and international literature), and consulted with relevant agencies, an independent expert panel, and other scientific experts. The ways that specific best practice approaches informed the pathways, risk assessment framework and additional measures are discussed throughout the report.

The risk assessment framework and pathways provide for reassessment of risk, with reassessment timeframes varying dependent on initial risk levels (see **Section 5.6**). The approach also provides for the EPA or FCNSW to nominate regions for reassessment if there is evidence that recovery is occurring at a different rate. If the region continues to recover, reassessment would allow for regions to be given a lower risk rating once nominated recovery thresholds are reached and commercial forestry operations are considered to pose a low risk in fire-affected areas. At this point, forestry operations would proceed under modified retention requirements or the standard Coastal IFOA prescriptions. The reassessment also allows for risk ratings to be increased in the event of further large-scale forest impacts, such as future fires.

The Commission considers that the standard Coastal IFOA prescriptions provide the necessary protections for the environment in low risk management zones, i.e. in areas where the fire extent and severity were similar to fire seasons prior to the 2019/20 wildfires. The Coastal IFOA was approved on the assumption that the comprehensive, adequate and representative (CAR) reserve system across tenures maintains adequate habitat in the landscape to minimise the impacts of harvesting at the site scale and the persistence of species at multiple scales. The terms of reference provided to the Commission does not ask for a review of standard prescriptions in the Coastal IFOA, and the Commission has not reviewed standard conditions and protocols.

[32] The terms of reference ask the Commission to recommend best practice approaches to manage forestry operations in fire-affected forests to satisfy the purposes of Part 5B of the *Forestry Act 2012*.

2.2 Management zone assessment results (Gateway 1)

For this advice, the Commission has undertaken the Gateway 1 analysis at the management zone scale, which allocates four risk ratings: low risk (green), medium risk (yellow), high risk (amber), and extreme risk (red). **Figure 4** shows the location of areas assigned to each risk rating from the management zone-scale risk assessment process.

The Commission's proposed risk assessment framework is designed to consider:

- high and extreme severity fire impacts from the 2019/20 wildfires (using DPIE-EES' FESM version 3) as the initial baseline at the management zone scale for the first assessment post-fire
- the recovery of those high and extreme impacts since fire (using DPIE-EES/DPI's post-fire spectral recovery index) at the local landscape area scale and at the management zones scale for future reassessments.

This approach draws on the best available data and science for decision-making. FESM version 3 provides a baseline (or reference point) from which to measure recovery. **Section 5.2** explains how FESM version 3 will be applied in the Gateway 1 assessment.

The post-fire spectral recovery index is an early version and requires further ground validation. However, it is the only available and practical way to undertake broadscale analysis of post-fire recovery dynamics at the appropriate scale for the Coastal IFOA region (landscape scale). This type of assessment is not possible to collect at the landscape scale from field assessments alone.

The Commission proposes the recovery index to be field validated at two scales:

- **at the operational scale** (i.e. local landscape area) during site assessments at Gateway 3 as part of the risk assessment process (**Chapter 5**)
- **at the broad landscape scale** through an agency-led, field campaign to sample sites across the Coastal IFOA region, concurrently but separate to the risk assessment process.

It is critical that further desktop planning and field assessment is undertaken to confirm the results of the Gateway 1 analysis and identify any operational-scale risks prior to harvesting or management to promote regeneration. The gateway 2 and 3 assessments would be conducted by FCNSW, concurrent with the existing process for planning forestry operations at the local landscape area.

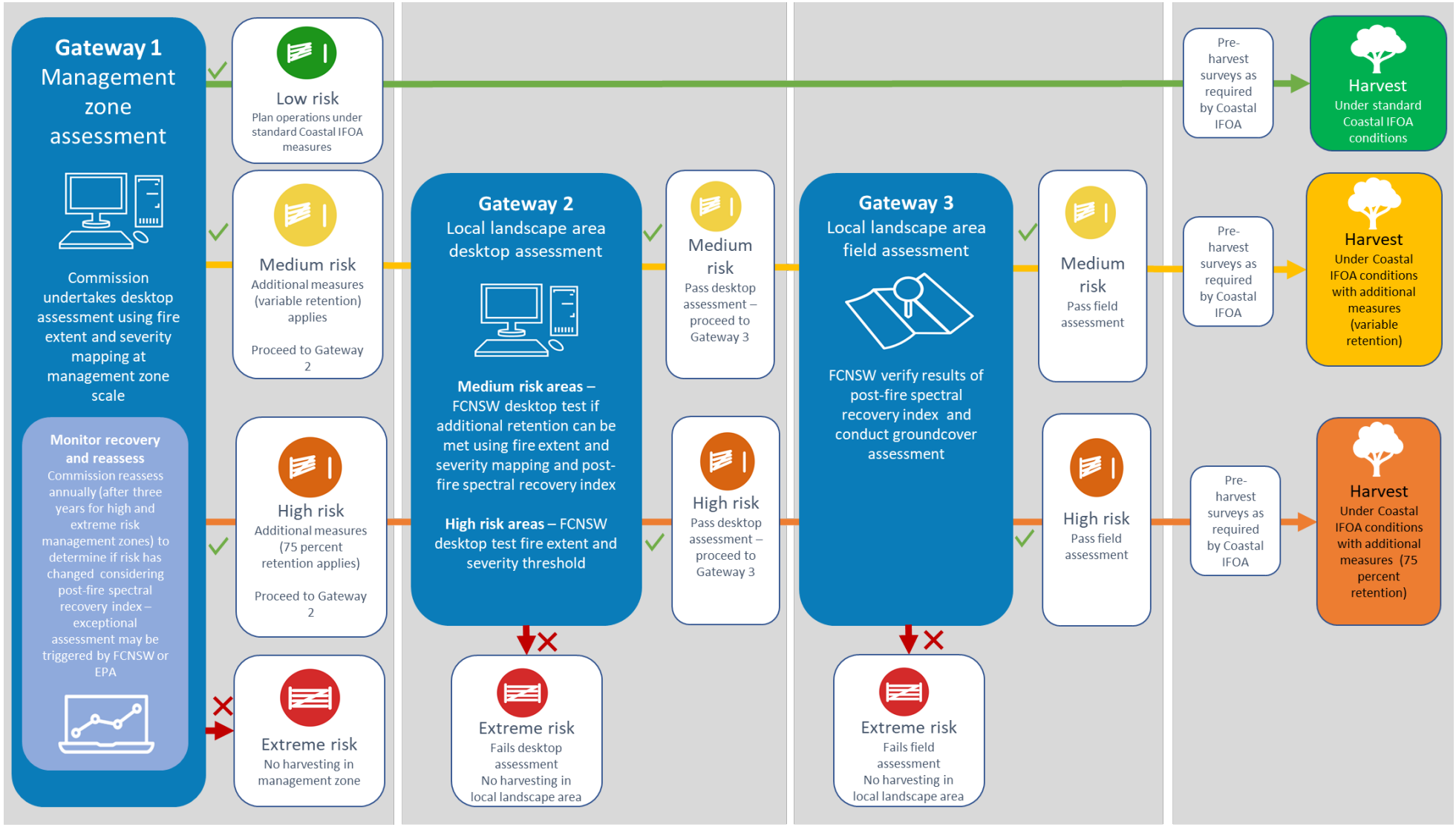

Figure 3: Risk and evidence-based framework used to determine pathways

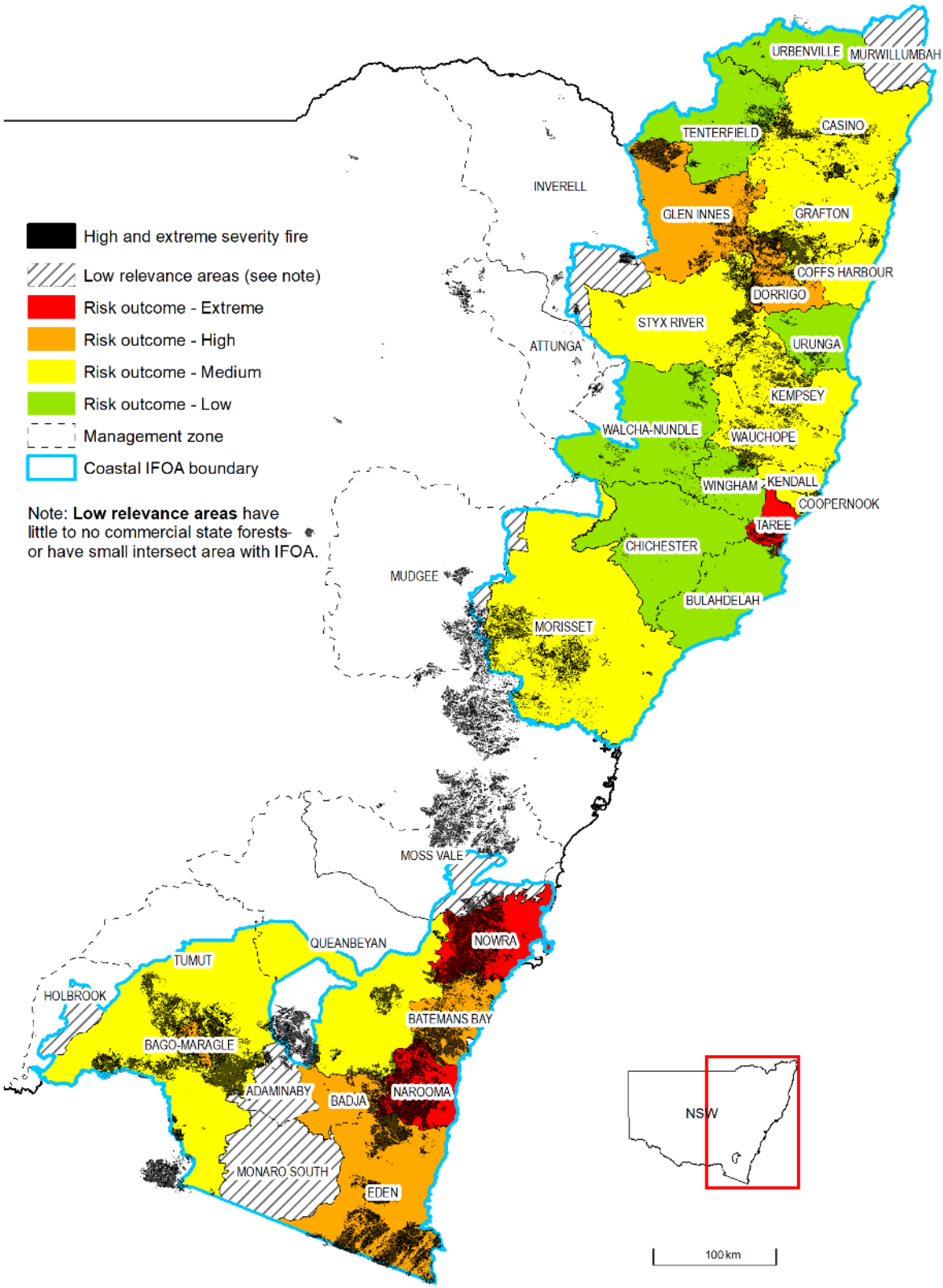

Figure 4: Risk assessment results by management zone

3 Impacts of pathways on wood supply and the timber industry

This chapter addresses the section of the terms of reference that asks the Commission to consider the implications of this review's recommendations and advise on their impact on wood supply and the timber industry.

- **Section 3.1** provides an overview of actual impacts on wood supply observed since the 2019/20 wildfires.
- **Section 3.2** outlines flow-on impacts from reductions in wood supply on local forest industries observed to date
- **Section 3.3** provides an overview of the forest industry context in the regions
- **Section 3.4** outlines analysis of potential impacts of the recommended pathways and risk mitigations on future wood supply
- **Section 3.5** outlines analysis of implications of the recommended pathways and risk mitigations on the forest industry.
- **Section 3.6** outlines future projections of sustainable wood supply.

3.1 Impacts on wood supply to date

The Commission analysed FCNSW's production data from the past 10 years to understand the impact of the 2019/20 wildfires on actual wood supply, finding that native forest wood supply declined sharply in all regions in 2020 as a direct result of the wildfires.

Timber production on the south coast (particularly in the South Coast and Eden subregions) was impacted more significantly than the north coast (see **Table 2** and **Figures 5-8**). This is attributed to the greater extent and severity of fire on the south coast and the lack of plantation resources to supplement harvesting of native forests in this region. While the supply of high quality (HQ)[33] logs from native forests fell significantly on the north coast, the overall impact of this was offset by the early harvesting of hardwood plantations.

Most notably, blackbutt (*E. pilularis*) plantation harvesting on the north coast increased five-fold in 2020 compared to the five-year average from 2015 to 2019, offsetting the fall in blackbutt supply from native forests. This early harvesting will affect the plantation age class distribution. However, advice from FCNSW indicates there will be limited impact on long-term plantation HQ log supply, with plantations providing around 25 to 30 percent of total HQ logs in the north coast over the long term.

The most heavily impacted commercial species were spotted gum species on the north and south coasts and silvertop ash (*E. sieberi*) on the south coast, both of which are important commercial species for the NSW timber industry.

[33] HQ logs from native forest are allocated to size classes: HQ large are logs meeting FCNSW's log specifications, including a centre diameter under bark of equal or greater than 40 centimetres, estimated as equivalent to equal or greater than 35 centimetres small end diameter under bark; HQ small are logs meeting FCNSW's log specifications, including a centre diameter under bark of equal or greater than 30 centimetres but less than 40 centimetres, estimated as equivalent to small end diameter under bark of equal or greater than 25 centimetres.

Table 2: Change in HQ log supply in 2020 compared to average of preceding five years

Subregion	Actual wood supply reduction in 2020 compared to average of preceding five years
South Coast	**84 percent reduction** in HQ log supply, primarily of spotted gum Down from 47,225 to 7,545 HQ m^3 Tablelands species harvest was extremely limited (less than 200 m^3 of HQ logs harvested)
Eden	**93 percent reduction** in HQ log supply, primarily of silvertop ash Down from 19,505 to 1,380 HQ m^3 Pulpwood supply also fell by 75 percent compared to the previous five years
Tumut	**2 percent reduction** in HQ alpine ash supply due to fire salvage operations supplementing production Down from 22,510 to 22,155 HQ m^3
North Coast	**19 percent overall reduction** in HQ log supply due to reductions in native forest production. However, FCNSW supplemented further losses by harvesting plantations. Down from 256,500 to 207,830 HQ m^3 Overall, blackbutt availability increased due to plantation harvesting Supply of other species fell overall: including north coast spotted gum (92 percent), and blue gum, tallowwood and brush box (35 percent) Native forest supply reduced by 58 percent

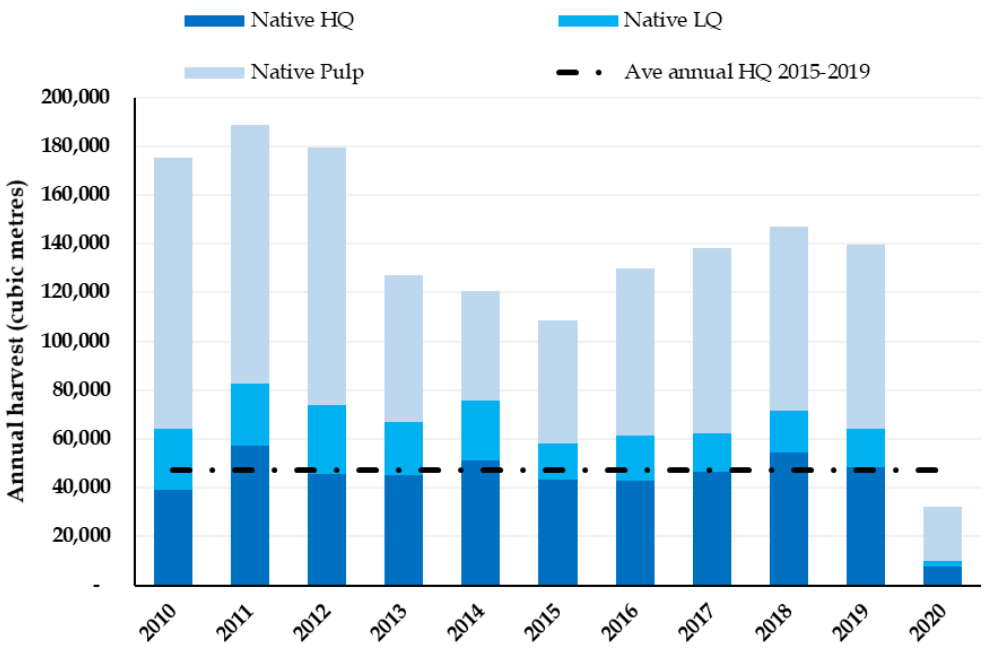

Figure 5: Actual annual wood supply from state forest by log class for the South Coast subregion compared to average annual HQ log supply for period 2015 to 2019

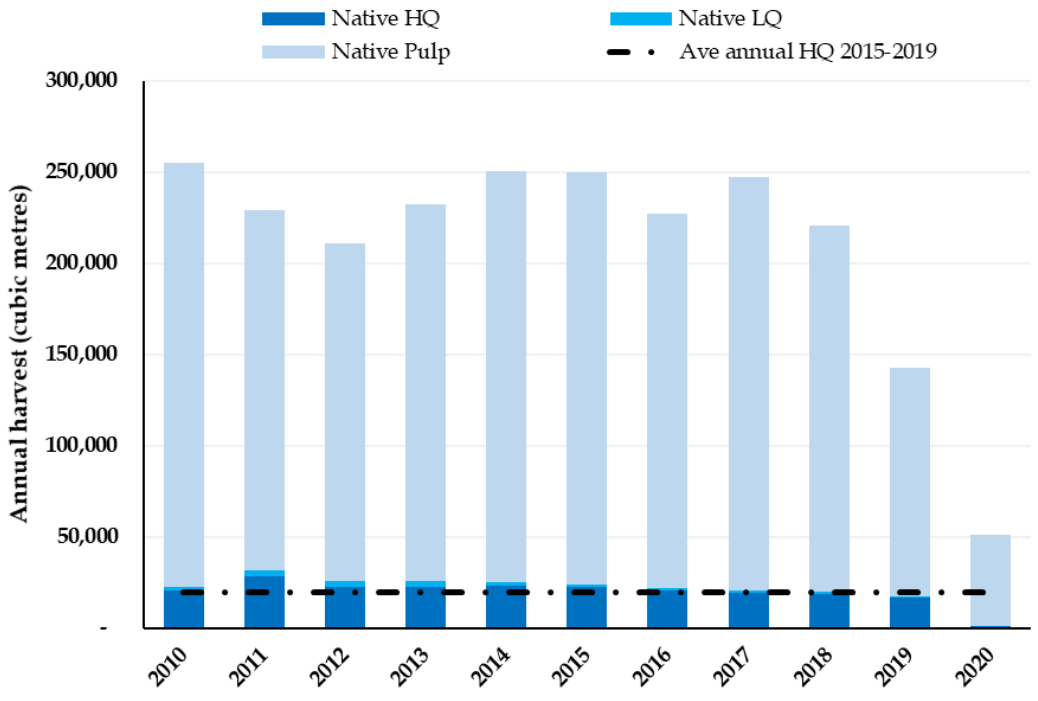

Figure 6: Actual annual wood supply from state forest by log class for the Eden subregion compared to average annual HQ log supply for period 2015 to 2019

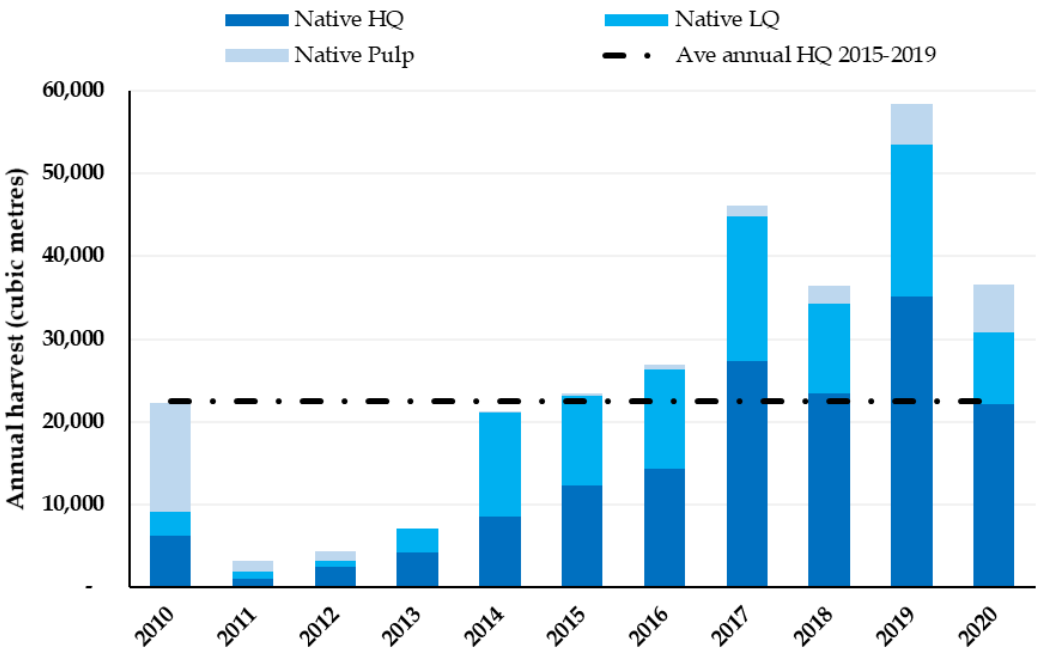

Figure 7: Actual annual wood supply from state forest by log class for the Tumut subregion compared to average annual HQ log supply for period 2015 to 2019

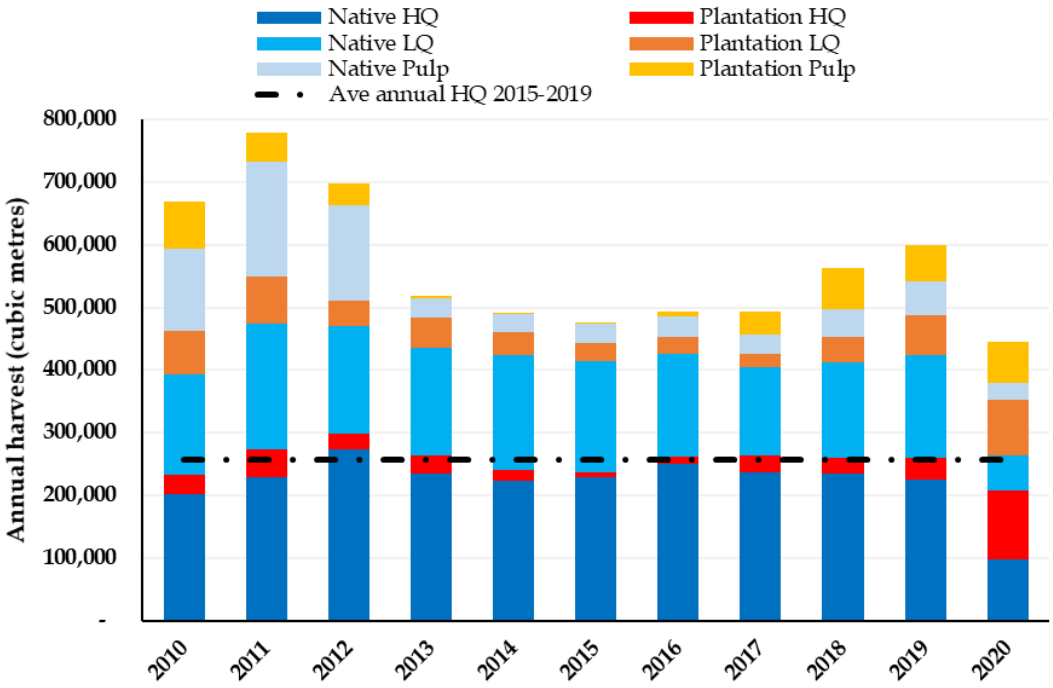

Figure 8: Actual annual wood supply from state forest by log class for the north coast subregions compared to average annual HQ log supply for period 2015 to 2019

3.2 Forest industry context

Table 3 presents data on the contribution of forestry and logging and wood product manufacturing industries[34] to employment and regional economies in an example set of local government areas (LGAs) in the Coastal IFOA region. These LGAs were selected as they are considered representative of where the regional contributions of native timber harvesting would be found (although it is noted that these figures comprise total forest industry, not just native hardwood harvesting in state forests).

While forestry and logging and wood product manufacturing contributes several million dollars to these regional economies, this contribution is often relatively less compared with other industries in the regions.

In terms of overall contribution to employment in these regions, these industries are relatively low (often less than 1 percent). Although in certain communities and towns such as Eden, the flow-on contribution of these industries should be considered in determining the broader employment impacts of the pathways.

[34] Data sourced from local government profiles at https://economy.id.com.au/ based on data from Australian Bureau of Statistics.

Table 3: Overview of employment and value add contribution of select regional forest industries[35]

		Forestry and logging in LGA 2019/20		Wood product manufacturing* in LGA 2019/20	
LGA	Relevant management area (sawmills)	Value added ($ million)	Employment (% of LGA employment)	Value added ($ million)	Employment (% of LGA employment)
South coast					
Bega Valley	Eden (includes pulpwood export facility and sawmill in Eden)	**26.8**	**1.0**	**5.1**	**0.7**
Eurobodalla	Narooma, part Batemans Bay (includes sawmill in Narooma)	**11.9**	**0.4**	**4.6**	**0.6**
Shoalhaven	Nowra, part Batemans Bay (includes sawmills in Nowra and Milton)	**2.3**	**0.0**	**26.0**	**1.3**
Snowy Valley	Bago-Maragle, Tumut (includes softwood plantation-based sawmills and paper production, hardwood sawmills located in northern Victoria not included)	**28**	**2.6**	**5.4**	**13.1**
Queanbeyan -Palerang	Queanbeyan (includes sawmill in Braidwood)	**2.2**	**0.1**	**20.5**	**2.3**
North coast					
Mid-Coast[36]	Bulahdelah, Taree, Wingham, Chichester (includes sawmills near Taree, Wingham and Buladelah)	**Data not available**	**0.1**	**Data not available**	**0.6**
Clarence Valley	Grafton, part Casino, part Dorrigo, part Coffs Harbour (mills include sawmills near Grafton)	**37.2**	**1.3**	**17.3**	**1.9**
Coffs Harbour	Coffs Harbour, part Urunga (includes sawmills near Coffs Harbour)	**38.3**	**0.7**	**6.0**	**0.4**

35 Data sourced from local government profiles at https://economy.id.com.au/ based on data from Australian Bureau of Statistics.

36 Data for Mid-Coast LGA not available for value added, employment data based on census not total corrected employment. Data from: https://economy.id.com.au/midcoast/.

Port Macquarie - Hastings	Part Wauchope, part Kendall, part Coopernook (includes sawmills near Wauchope)	**20.0**	**0.3**	**13.9**	**0.8**

*wood product manufacturing includes subcategories 'Log Sawmilling and Timber Dressing', 'Other Wood Product Manufacturing' and 'Wood Product Manufacturing not further defined'

3.3 Impacts on industry to date

There are no published studies of the flow-on impacts of reduced wood supply on the NSW timber industry. Based on advice from FCNSW, while there have not yet been any mill closures as a direct result of the wildfires, some are at risk of closure unless supply can be increased and there is certainty of ongoing supply.

FCNSW declared *force majeure* on many wood supply agreements in the south coast and north coast, impacting employment in forest operations, log haulage, timber processing, and allied services. Some new short-term sales agreements have commenced on the south coast, as their long-term wood supply agreements have recently expired. The Commission received advice from FCNSW that, while several sawmills on the south coast continue to operate on minimal log intakes from FCNSW, they have supplemented their supply where possible from private property sources. However, mill operators have advised FCNSW that this cannot continue in the short to medium term.

There have been reductions in work shifts and some redundancies in regions where wood supply was substantially reduced. Many sections of the industry remain in a tenuous position as the availability of log supply from state forest has been very low and alternative sources are not available. An estimate of direct jobs in the hardwood sector that were considered at risk in coming months in the south coast and Eden regions as a result of the wildfires were provided at Budget Estimates.[37] **Table 4** summarises these estimates.[38] As of March 2021, a stand down of up to 74 harvest and haulage jobs and 6 jobs at a sawmill in the region has been reported.[39]

The Narooma and Nowra sawmills remain at risk due to lack of sawlog supplies from FCNSW. Mountain Hardwoods Pty Ltd in Tumut and the Braidwood Sawmill in the South Coast subregion are almost exclusively supplied by FCNSW and are considered by FCNSW to be at risk of imminent closure. South Coast Hardwoods Pty Ltd in the Eden subregion is not a current customer of FCNSW but is understood to have limited current log supply options. Allied Natural Wood Exports has received reduced supplies from FCNSW and, while currently supplementing their export chip markets with supplies from interstate, this is unlikely to be

37 Parliament of NSW (2021) *Budget Estimates 2020-2021 Supplementary Questions, Portfolio Committee No. 4 – Industry*. Available at: https://www.parliament.nsw.gov.au/lcdocs/other/15367/Answers%20to%20supplementary%20questions%20-%20Barilaro.pdf.

38 Parliament of NSW (2021) *Budget Estimates 2020-2021 Supplementary Questions, Portfolio Committee No. 4 – Industry*. Available at: https://www.parliament.nsw.gov.au/lcdocs/other/14221/Compiled%20supplementary%20questions%20-%20PC%204%20-Deputy%20Premier,%20Regional%20NSW,%20Industry%20and%20Trade%20-%20%20Budget%20Estimates%202020-2021.pdf.

39 Parliament of NSW (2021) *Budget Estimates 2020-2021 Supplementary Questions, Portfolio Committee No. 4 – Industry*. Available at: https://www.parliament.nsw.gov.au/lcdocs/other/15367/Answers%20to%20supplementary%20questions%20-%20Barilaro.pdf.

sustainable. Allied Natural Wood Exports is also expected to soon complete construction of a new sawmill near Eden to process sawlog under a wood supply agreement with FCNSW that runs until 2028.

Table 4: Summary of direct jobs at risk in the hardwood sector of the south coast provided to Budget Estimates in September 2020

	South Coast	Eden	Tumut	Total
Mills	65	74	97	236
Contractors	34	60	20	114
FCNSW staff	35	27	3	65
				415

North coast timber harvest and haulage contractors and timber processors have also been impacted by reduced quantity, as well as different species mixes and log sizes. FCNSW advised that the 2019/20 wildfires shifted harvesting focus to blackbutt plantations in the short term. FCNSW advise that there are few mature hardwood plantations available to continue to supply timber in these quantities and a return to largely native supply is required to maintain normal supply volumes.

While benefitting some processors, the shift to blackbutt plantations impacted supply of other species traditionally required for specialty strength, durability and appearance (for products such as power poles, piles, girders, key structural timbers and flooring). Impacted companies include J Notaras & Sons Pty Ltd, Koppers Wood Products Pty Ltd, Coffs Harbour Hardwoods Pty Ltd, Dale and Meyers Operations Pty Ltd, Williams Timber Pty Ltd and Ironwood Taree Pty Ltd.

There has also been an impact on processors of low-quality logs typically produced as a by-product of HQ log harvesting operations, as a smaller volume of this log grade is produced from plantations. Impacted mills include Adams Sawmills Pty Ltd, Aquafern Pty Ltd, Henson Sawmilling Pty Ltd, Thora Sawmilling Pty Ltd, Hayden Sawmilling Pty Ltd, Hurford Hardwood Kempsey Pty Ltd, Newells Creek Sawmilling Pty Ltd, and RA Sweetman & Sons Pty Ltd.

Smaller, family-owned businesses that rely on supplies of durable species for fencing and firewood have potentially been more impacted. This includes small mills such as Caban Sawmilling Pty Ltd and Noel Marsh Sawmilling Pty Ltd in the Hunter region.

The significant impact on spotted gum production in the short and longer term is a risk to the profitability of hardwood flooring producers on the north coast. This will include producers such as Hurford Hardwoods Pty Ltd, J Notaras & Sons Pty Ltd, Big River Timbers Pty Ltd and also the producers of power poles, piles and girders.

FCNSW is assessing the need for further *force majeure* provisions for some major wood supply agreement obligations. More recently, FCNSW has also separately applied *force majeure* in relation to the flood event from early 2021.

3.4 Potential short-term impacts of the pathways on wood supply

The pathways recommended in this review assign a set of operational rules for management zones based on four risk ratings. For this review, FCNSW with oversight by the Commission analysed the potential wood availability and wood supply under the recommended pathways, based on a scenario of progressive recovery. Risk ratings were assigned for each management zone for three time periods (**Table 5**), based on preliminary scenario analysis using projected recovery[40] (noting periods 2 and 3 have considerable uncertainties due to limited ground validated data on forest recovery to date).

Based on these risk ratings, a preliminary analysis by FCNSW applied the Commission's recommended additional measures to local landscape areas with existing operational plans through a desktop assessment of spatial data. This allowed a preliminary analysis of the impact of the proposed pathways and mitigation measures to be conducted for each management zone to determine if there is sufficient net harvest area to meet short-term wood supply demand in that management zone.

FCNSW used both spatial analysis and professional judgement to determine the likely impact on wood supply for each management zone, including assessing:

- the proportion of each local landscape area affected by different fire severities and their distribution across each local landscape area
- the location of the most suitable lightly burnt forest to achieve temporary refuge objectives
- access to and within compartments comprising each local landscape area
- proximity (transport distance) of the local landscape area to markets for log products and species.

The Commission notes that there are several limitations and challenges associated with this assessment, which represents a conservative lower-end estimate of wood supply. These are discussed in more detail below.

40 Based on DPI Forest Science's post-fire spectral recovery index preliminary version described in **Section 5.1**.

Table 5: Projected management zone risk rating for scenario analysis from June 2021 to December 2025

	Projected risk rating by time period		
Management zone	**Period 1 June 2021 to February 2022**	**Period 2 March 2022 to February 2023**	**Period 3 March 2023 to December 2025**
Bulahdelah	Low	Low	Low
Chichester	Low	Low	Low
Tenterfield	Low	Low	Low
Urbenville	Low	Low	Low
Urunga	Low	Low	Low
Walcha-Nundle	Low	Low	Low
Wingham	Low	Low	Low
Casino	Medium	Low	Low
Coffs Harbour	Medium	Low	Low
Grafton	Medium	Low	Low
Kendall	Medium	Low	Low
Coopernook	Medium	Medium	Low
Kempsey	Medium	Medium	Low
Morisset	Medium	Medium	Low
Queanbeyan	Medium	Medium	Low
Tumut	Medium	Medium	Low
Wauchope	Medium	Medium	Low
Styx River	Medium	Medium	Medium
Dorrigo	High	High	Medium
Glen Innes	High	High	Medium
Batemans Bay	High	High	Medium
Eden	High	High	Medium
Badja	High	High	High
Bago-Maragle	High	High	High
Taree	Extreme	Extreme	Medium
Narooma	Extreme	Extreme	High
Nowra	Extreme	Extreme	High

Significant short-term impacts are likely on the south coast, with smaller impacts on the north coast

Table 6 shows the results of FCNSW's preliminary assessment for each subregion. Impacts were most severe in the South Coast subregion, where there may be up to an 80-90 percent reduction in planned wood supply volume. The significant reduction is driven by suspension of harvesting in the Nowra and Narooma management zones, which received extreme risk ratings. Available supply in Batemans Bay is also highly impacted (around 85 percent reduction) due to the small proportion of high and extreme fire impacts in forests north of Batemans Bay (less than 10 percent) making those forests focal areas for refugia and therefore unavailable for harvesting. Further, in the remaining areas, scattered distribution of refuge requirements reduces the viability of harvesting operations.

Table 6: Potential wood supply impacts based on FCNSW analysis

Subregion	Actual wood supply reduction in 2020 compared to average of preceding five years	Estimated short-term wood supply reduction due to proposed risk mitigations as proportion of wood supply agreement volumes[41]	Wood supply agreement term
South Coast	**84 percent reduction** in HQ log supply, primarily of spotted gum	**80 to 90 percent reduction** in total wood supply from native state forests	2 x 1 year (sawlog) 1 x 15 years (pulpwood)
Eden	**93 percent reduction** in HQ log supply, primarily of silvertop ash	**40 percent reduction** in total wood supply from native state forests	1 x 10 years (sawlog) 1 x 15 years (pulpwood)
Tumut	**2 percent reduction** in HQ alpine ash supply due to fire salvage operations supplementing production	**35 percent reduction** in total wood supply from native state forests	1 x 10 years (sawlog) 2 x 1 year (sawlog)
North Coast	**19 percent overall reduction** in HQ log supply due to reductions in native forest production.	**10 to 20 percent reduction** in total wood supply from native and plantation state forests	45 x 2.5 years (sawlog) 1 x 7.5 years (sawlog) 1 x 2.5 years (pulpwood)

Most of the limited supply will come from the Queanbeyan management zone. Although this area has supplied low volumes in recent years, FCNSW expects some wood supply to be available, primarily from unburnt forests, although this will be a different species mix from planned operations in coastal forests.

The cumulative impact of these wood supply reductions needs to be determined through immediate consultation with industry, including to consider its economic viability on the south coast.

41 Short-term wood supply was modelled for local landscape areas within existing operational plans which apply for approximately 18 months (end of 2022).

In the Eden subregion, refuge requirements are expected to reduce available wood supply volume by 40 percent. These impacts, while not as large as in the South Coast subregion, are still significant.

In the Tumut subregion there will be a reduction in supply of approximately 35 percent of wood supply agreement volume.

Based on analysis provided by FCNSW, planned wood supply may be reduced by 10-20 percent in north coast subregions under the proposed pathways. Reduction in overall supply in the north coast is mainly due to the Gateway 1 risk ratings in the Taree, Dorrigo and Glen Innes management zones. This is due either to harvesting suspension under an extreme risk rating (Taree), or inability to meet refuge requirements in the additional measures. There are also several local landscape areas where operations could proceed but with reduced wood availability due to refuge requirements.

In the north coast and Eden subregions, FCNSW consider that impacts on the current plan of operations could be mitigated over time by undertaking additional planning of alterative areas where harvesting can occur. However, this process may take up to 12 months to implement before mitigations could be realised and would require sustained significant additional resources in tactical planning, operational planning and ecological surveys for a number of years until management zones transition to a low risk rating.

Limitations of current short-term estimates

There are several limitations associated with the current estimates of short-term wood supply impact. The analysis was constrained by the number of local landscape areas with sufficiently advanced operational plans to model the potential impact of the additional measures,[42] noting that the ongoing program to develop operational plans has been affected by the 2019/20 wildfires and subsequent uncertainty about where operations can occur and the safety of field surveys. The number and location of local landscape areas with completed operational plans varies by management zone, with the north coast subregions having more completed than the South Coast and Eden subregions.

FCNSW has advised that the potential impact of the recommendations on timber supply cannot currently be estimated with a high level of confidence. A more detailed understanding on how gateways 2 and 3 are practically applied on-ground is needed to provide a more accurate estimate of short- to medium-term impacts on wood supply. FCNSW has recommended the application of smoothed FESM data to reduce the potential operational issues created from using 10-metre pixels in the base FESM data. Further, where there are gaps or errors in FESM, the use of FCNSW's Rapid Assessment of Fire Impact on Timber (RAFIT) data can improve overall accuracy of mapping. The adoption of smoothed FESM and spectral recovery data (discussed in **Section 5.1**) and infilling of gaps in FESM data with RAFIT data may result in a small increase in the net harvest area available for harvesting and consequently in wood supply availability.

[42] Operational plans are prepared by FCNSW for compartments/coupes in local landscape areas based on desktop spatial and quantitative analysis that considers ecological values, topography, disturbance history, access and predicted wood availability. Field surveys may also be undertaken at the planning stage. Once planned, compartments/coupes are included in an annual plan of operations that details areas to be harvested to meet wood supply commitments and silvicultural objectives.

3.5 Potential impacts of the pathways on the forest industry

The terms of reference requested the Commission assess the potential impacts of the recommended pathways on industry based on FCNSW's short-term wood supply estimates.

The Commission undertook an analysis that considered the potential impacts on the forest industry from applying the pathways and risk mitigations recommended in this report. This considered the estimated reductions in wood supply discussed in **Section 3.4**. However, there was no NSW-specific data on the correlation between wood volumes and employment. Further, under the terms of reference the Commission was not able to consult with the forestry sector or forest industry, which also impacted the accuracy of estimates.

As discussed in **Section 3.2**, the Commission was advised by FCNSW that reductions in wood availability from the wildfires themselves has already impacted on industry, including reductions in work shifts and some redundancies. Budget Estimates 2020/21 provided an estimate of potential forestry industry jobs at risk 'in the coming months' (**Table 4**). As of March 2021, 74 harvest and haulage jobs and 6 jobs at a sawmill in the region were stood down.[43] It is difficult to determine the difference between employment impacts under SSOCs and FCNSW voluntary measures and the recommended pathways and risk mitigations.

The results of this assessment are provided in the following section. Overall, the estimates suggest that over half the forestry jobs in the south coast subregions are at significant risk at least in the short term and potentially longer if mills are no longer viable at reduced supply levels. However, noting the significant limitations in available data, these estimates should be used cautiously and be immediately updated based upon actual jobs data following consultation with industry and more detailed industry impact assessment.

The terms of reference did not ask the Commission to advise on recommended actions to address or mitigate potential impacts on industry. It is also not practical to do this given the uncertainties in the current analysis described above. Industry should be consulted to enable NSW Government to quantify the impacts of the measures proposed in the recommendations in this report. Forest industry impacts and the flow-on effects and impacts to the broader community will be strongly dependent on region-specific factors. Regional factors that should be considered in determining the broader employment impacts of the pathways include:

- ongoing impacts on regional economies from major events, including the 2019/20 wildfires, significant flood events and Covid-19
- the contribution of the forestry industry in smaller communities to overall employment in the area.

Analysis of potential jobs at risk under recommended risk mitigations

Unlike other states, there are no NSW-specific assessments of the relationship between the volume of timber harvested and the number of jobs within the native forest sector. Forest and Wood Products Australia has supported a comprehensive project to develop methods and data to understand the social and economic effects of the forest industry in regional economies, with

[43] Parliament of NSW (2021) *Budget Estimates 2020-2021 Supplementary Questions, Portfolio Committee No. 4 – Industry*. Available at: https://www.parliament.nsw.gov.au/lcdocs/other/15367/Answers%20to%20supplementary%20questions%20-%20Barilaro.pdf.

the final report due to be completed soon.[44] This project, with additional support from state governments, covered the native forest industry in Western Australia[45], Tasmania[46], Victoria[47] and Queensland. It provided comprehensive data on employment in the forest industry for all local government areas in the study regions.

In the absence of similar published data for native forestry regions in NSW, the best data available in NSW are the five-yearly national Australian Bureau of Statistics census, DPI performance insights and more recent information from regional development strategies.[48] However, these do not sufficiently disaggregate data to enable the level of analysis needed to assess the impact of the pathways on the forest industry.

Investment in reliable employment data is essential to support evidence-based decision-making about the impacts of alternative pathways. The NSW Forest Monitoring and Improvement Program has a current project to develop a method to quantify forest-dependent jobs in NSW. Consistent implementation of the method will build an evidence base to support future decision-making.

Given the current limited data in NSW, the Commission has relied on the assessments for other states with similar conditions to Coastal IFOA regions to infer indicative impacts for employment in the native forest industry and regional communities.

With the circumstances raised above, these estimates reflect the best available (albeit limited) data. However, there are considerable limitations with this approach and figures should be used with caution.

The interstate studies assessed the total number of direct and flow-on jobs in the forest industry.

- Direct jobs – jobs involved in the forestry supply chain from the point of forest management and harvest planning and operations, through to and including primary processing of the log products
- Flow-on jobs – production-induced jobs (suppliers to the supply chains i.e. fuel purchase, purchase of mechanical or accounting services) and consumption-induced jobs (i.e. where supply chain workers spend their wages on goods and services).

This information was used to infer employment ratios for the NSW industry analysis (**Table 7**). The job ratio in the Eden subregion is relatively lower compared to the South Coast, Tumut and north coast ratios due to the higher proportion of pulpwood processing in the Eden subregion, which is typically less labour intensive than sawmilling.

44 Forest and Wood Products Australia (2021) *Understanding the social and economic effects of the forest industry in regional communities.* Available at: https://www.fwpa.com.au/resources/reports/other/2010-understanding-the-social-and-economic-effects-of-the-forest-industry-in-regional-communities-sae003-1516.html.

45 Schirmer, J. Mylek, M. Magnusson, A. Yabsley, B. Morison, J. (2017) *Socio-economic impacts of the forest industry: Western Australia*. Report produced for Forest and Wood Products Australia by the University of Canberra.

46 Schirmer, J., Mylek, M., Magnusson, A., Yabsley, B. and Morison, J. (2018) *Socio-economic impacts of the forest industry: Victoria (excluding Green Triangle)*. Report produced for Forest and Wood Products Australia by the University of Canberra.

47 Schirmer, J., Mylek, M., Magnusson, A., Yabsley, B. and Morison, J. (2018) *Socio-economic impacts of the forest industry: Tasmania.* Report produced for Forest and Wood Products Australia by the University of Canberra.

48 Department of Regional NSW (2020) *REDS bushfire addenda*. Available at: https://www.nsw.gov.au/regional-nsw/regional-economic-development-strategies/reds-bushfire-addenda.

Table 7: Inferred direct forest industry and flow-on jobs in each subregion

	Number of jobs per 1000 m³ of wood supply	
Subregion	**Direct jobs**	**Flow-on**
Eden	1.0	1.0
South Coast and Tumut	1.25	1.0
North Coast	1.25	1.0

There are likely to be significant jobs at risk at least in the short term in south coast subregions, with mill viability also at risk

Based on the ratios in **Table 7** and the estimated change in short-term wood supply volumes under the recommended pathways, there is a risk of significant reduction in direct jobs in the south coast subregions.

Table 8 summarises estimated direct job reductions for each subregion that might have been generated from historical supply, and then employment that might arise where employment is based solely on a pro-rata basis of FCNSW estimates of available volume when recommended risk mitigations are implemented. The estimates recognise where the location of the processing occurs.

This represents cumulative impacts on business profitability of prolonged changes to species mix and wood supply volume and the consequent demand for labour, goods and services by forestry contractors and wood manufacturing businesses.

Table 8: Estimated direct jobs following the 2019/20 wildfires and recommended risk mitigations in south coast subregions*

	Processing location (subregion)			
	South Coast	**Eden**	**Tumut**	**Total for south coast subregions**
Estimated direct jobs pre-2019/20 wildfires	67	250**	15***	332
Estimated direct jobs after recommended pathways and risk mitigations	6-13	110-130**	8-12***	124-155

*Note the Commission has low confidence in these numbers given the uncertainty and lack of data.
**Assumes pulpwood employment arises in Eden while fibre sourced is from both South Coast and Eden subregions. Pulpwood and HQ sawlog production socioeconomic impact is likely to be spread across the Eden subregion and southern portions of the South Coast subregion.
***Given sawmilling predominantly occurs in Victoria, this employment figure assumes only harvest and haulage contribution of HQ log supply from NSW, equivalent to 50 percent of applied ratio.

The use of a pro-rata approach to estimating potential impacts is limited, as it ignores the reality of operating processing facilities, particularly the need for a facility to have sufficient throughput to maintain a competitive position in their respective marketplace. Each of the facilities using wood supplied from FCNSW operate in highly competitive and accessible wood

production marketplaces, competing in wood products markets directly with other domestic producers as well as international competitors.

To provide a more informed consideration of the impact of major reductions in available supply, **Table 9** provides examples of facility-level impacts at the four major processors in the South Coast and Eden subregions. Wood from the Tumut subregion is processed in Victoria, with job losses all related to harvesting and haulage.

In the South Coast subregion, the Nowra and Narooma sawmills have been long-term recipients of FCNSW supplies. Expected potential volumes for these mills are well below what is needed to sustain both facilities. There is potential for both mills to close.

In Eden, the reductions in wood supply would likely lead to lower operating levels for both current and planned mills. The Eden sawmill – due to open in July 2021 – may find it very challenging to be a competitive processor at the projected reduced scale, with resultant uncertainty around project development. The Eden wood-chipping facility may also find it difficult to supply international markets at the projected reduced scale, with viability also impacted by the status of the Eden sawmill.

Table 9: Short-term facility-level employment impacts at key locations

Location	Assumed historical production (m^3/year)	Indicative post-fire settings production (m^3/year)	Estimated jobs at risk
Nowra	~20,000 dominated by the preferred species spotted gum	Nil – assumed no supply from traditional areas, and little to no availability in abutting areas. Assumed more likely for any South Coast supply to be redirected to Narooma.	20-30 direct jobs
Narooma	~20,000 dominated by the preferred species spotted gum	Could be 5-10,000 m^3/ year of highly variable species mix	10-15 direct jobs
Eden sawmilling	~27,000 predominantly featuring two or three main species but highly diverse overall supply	Supply could be 10-14,000 m^3 /year of highly variable species mix	15-20 direct jobs once mill is constructed and operational
Eden wood-chipping	~225,000 dominated by supply from Eden subregion, supplemented from South Coast and Tumut subregions	Supply defined by sawlog harvest, and could be in the vicinity of 80-95,000 m^3 /year	80-100 direct jobs, spread across the Eden and lower South Coast subregions

Multipliers determined from interstate studies indicate that the number of additional flow-on jobs at risk by the pathways could be roughly equivalent to the number of direct jobs at risk. However, the Commission notes there is considerable uncertainty around these figures, and they should be applied with caution.

North Coast subregions could see a relatively smaller level of jobs at risk, but the location of impact is difficult to determine

Table 10 shows the estimated number of direct jobs at risk in north coast subregions based on the ratios in **Table 7** and the estimated change in wood supply volumes under the recommended pathways. Based on the expected fall in wood supply volumes on the north coast of 10-20 percent, there is expected to be a smaller number of direct jobs at risk in the north coast subregions compared with the south coast subregions. It is also more likely any job losses will be temporary on the north coast given anticipated recovery rates.

However, there are several contextual factors that make the accurate assessment of potential losses difficult, as well as identifying where impacts might arise across the north coast. Since the 2019/20 wildfires, native forest wood supply reductions have been supplemented by a focus on harvesting native hardwood plantations. This assessment has not included a review of the potential capacity of the north coast plantation assets to provide a meaningful ongoing supply. However, FCNSW advised the potential for supply from plantations is now very limited. There are significantly fewer areas of mature plantation left available. Long-term impacts on plantation supply are not expected as plantations are replanted following harvesting.

While overall risk to north coast jobs could be reflective of the expected reduction in harvest levels from 2021 through to 2022/23, the location of the impact could also be driven by a range of factors including:

- the potential to secure supplementary supply from private native forest, recognising that the north coast industry has traditionally gained a supply from private native forest and considering whether this supply source has a realizable potential to increase log availability
- the capacity of FCNSW to redirect potential subregion supply-demand imbalances (i.e. moving logs over distance well beyond typical haulage distance from areas with additional log availability to wood processing hubs will shortfalls in supply)
- the capacity of industry to use an increasing proportion of less preferred timber species (i.e. New England Group of species) which may also incur extraordinary harvest and haulage costs to make available to coastal based processing facilities.

Table 10: Estimated direct jobs following impact of the 2019/20 wildfires and recommended risk mitigations in north coast subregions*

	Processing location (subregion)
	North coast subregions
Estimated direct jobs pre-2019/20 wildfires	590
Estimated direct jobs after recommended pathways and risk mitigations	Approx. 500**

*Note the Commission has low confidence in these numbers given the uncertainty and lack of data.
*Job numbers will depend on the level of wood supply from private native forest, the capacity of mills to use alternative species than their traditional mix, and the capacity of FCNSW to redirect supply to resolve demand imbalances within the region

As with the south coast subregions, multipliers determined from interstate studies indicate that the number of additional flow-on jobs impacted by the pathways could be roughly equivalent to the number of direct jobs at risk. However, the Commission notes there is considerable uncertainty around these figures, and they should be applied with caution.

3.6 Future projections of sustainable wood supply

Short-term projections of forest recovery

Given the dynamic nature of forest ecosystems, as well as limitations in data availability and time, it was not feasible to provide accurate estimates of when all forests burnt at higher severity will recover to the extent that they are considered low risk and able to have harvesting operations occur under standard Coastal IFOA conditions. However, the Commission considers it is reasonable to expect that north coast forests will continue to experience higher rates of recovery than south coast forests in the short to medium term.[49] This is largely due to north coast forests being more productive forests with higher rainfall than southern forests.[50]
Given the range of uncertainties in forest recovery, the Commission used multiple lines of evidence[51] to estimate which management zones are most likely to change from medium to low risk by 2022 (assuming any fires in 2021/22 have low impact). These are:

- Casino
- Coffs Harbour
- Grafton
- Kendall.

Further, estimates are that there may potentially be an additional six management zones that change from medium to low risk by 2023, with five potentially changing from high or extreme to medium risk as set out in **Table 5**. Other zones may also change as forests recover. The Commission has greater confidence in its projections on zones moving from medium risk to low risk, given the extent of impacts and higher uncertainty of recovery in the other zones. Again, these are preliminary projections with several assumptions (including the upcoming fire season having relatively low impact), which need to be tested through extensive field work and recovery monitoring.

49 Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review; Gibson, K.R. and Hislop, S. (MS) *Signs of resilience in resprouting Eucalyptus forests, but areas of concern: One year of post-fire recovery from Australia's Black Summer 0f 2019-20*. Submitted to PNAS.

50 *Ibid.*

51 DPI Forest Science preliminary predicted recovery model, DPIE EES/DPI Forest Science post-fire spectral recovery index, 2Rog literature review of forest type recovery and the University of Wollongong study into fire regimes under the Coastal IFOA monitoring program

Long-term sustainable yield

There will likely be ongoing long-term impacts to projected wood supply (sustainable yield) from the 2019/20 wildfires. This was noted in the review[52] published by FCNSW in December 2020 that remodelled 100-year sustainable yield forecast using FRAMES[53] considering the impacts of 2019/20 wildfires across the North Coast, South Coast, Eden and Tumut subregions.

The FCNSW post-fire modelling, completed in the first half of 2020, used early field observations of the post-fire condition of state forests, spatial data and available forest inventory data to modify modelling assumptions, including relaxing the non-declining yield constraint for the initial planning periods (10 to 20 years) to allow for short-term salvage harvesting of valuable burnt timber. FCNSW advised that sustainable yield analysis for the Tumut subregion is being rerun using recently collected data.

The post-fire modelling was independently reviewed by an expert in forest modelling[54] and found to be reasonable given the limited safe access to forests for on-ground remeasurement.[55] The review noted that the assumptions about immediate fire induced mortality, product degrade, interruption of tree growth and regeneration were supported by measurements of a previously burnt site, but these assumptions should be reviewed once repeated field measurements are safe and practical. The review recommended sensitivity analysis of key assumptions be undertaken, and monitoring of successful regeneration and tree form post-fire and under potential climate change scenarios will be important.

The post-fire sustainable yield estimates provide an indication of potential long-term trends in availability of HQ logs at the Coastal IFOA subregion scale compared with previous forecasts, with variation in impacts across regions and species (see **Table 11** and **Figures 9-12**).

The largest impacts in the medium-term (to 2034) are estimated to occur in the South Coast and Tumut subregions (-30 and -27 percent respectively), with lesser impacts in Eden and the North Coast subregions (-13 and -4 percent respectively).[56]

Overall, there is likely to be an earlier shift to smaller diameter HQ logs and less-preferred timber species, with the largest difference on the south coast where supply cannot be supplemented by plantations. This may bring forward the need for changes to the timber processing industry and marketing of products from these regions to accommodate different size and species of logs processed and the resultant change in product mix.

---

52 FCNSW (2020) *2019–20 Wildfires NSW Coastal Hardwood Forests Sustainable Yield Review*. Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1299388/fcnsw-sustainable-yield-report-2019-20-wildfires.pdf.

53 FRAMES (the Forest Resource and Management Evaluation System) is used by FCNSW to project long-term wood supply based on yield models derived from measurement of an extensive system of permanent growth plots.

54 Associate Professor Cris Brack, Fenner School of Environment and Society, Australian National University.

55 Brack, C. (2020) *Independent Review Post Fire Resources*. Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0012/1299387/fcnsw-independent-review-of-fire-resources.pdf.

56 FCNSW (2020) *2019–20 Wildfires NSW Coastal Hardwood Forests Sustainable Yield Review*. Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1299388/fcnsw-sustainable-yield-report-2019-20-wildfires.pdf.

Table 11: Summary of actual wood supply reduction and modelled impacts to sustainable yield

Subregion	Actual wood supply reduction in 2020 compared to average of preceding five years	Potential long-term impacts in wood supply (sustainable yield)
South Coast	**84 percent reduction** in HQ log supply, primarily of spotted gum Tablelands species harvest was extremely limited (less than 200 cubic metres of HQ logs harvested)	A potentially large fall in HQ log availability of 30 percent over the next 20 years compared to pre-fire projections, particularly in the availability of spotted gum, which will increase reliance on other species and impact customers with a focus on processing spotted gum
Eden	**93 percent reduction** in HQ log supply, primarily of silvertop ash Pulpwood supply also fell by 75 percent compared to the previous five years	A medium-term decline of 13 percent to 2034 compared to pre-fire projections followed by a long-term decline in HQ log availability of almost 30 percent Small diameter logs will dominate supply as regrowth matures
Tumut	**2 percent reduction** in HQ alpine ash (*E. delegatensis*) supply due to fire salvage operations supplementing production	Supply over the next 20 years is projected to be 25 percent below pre-fire forecasts, following salvage harvesting of fire-killed alpine ash in the next 2 years Logs with diameter smaller than traditional sawlogs will dominate long-term supply as regrowth matures
North Coast	**19 percent overall reduction** in HQ log supply due to reductions in native forest production. However, FCNSW supplemented further losses by accessing plantation harvesting Overall, blackbutt availability increased due to plantation harvesting Supply of other species fell overall: including north coast spotted gum (92 percent), and blue gum, tallowwood and brush box (35 percent) Native forest supply reduced by 58 percent	Supply over the next 20 years is projected to be less than 5 percent below pre-fire forecasts The proportion of smaller diameter logs will increase from plantations and post-fire regrowth

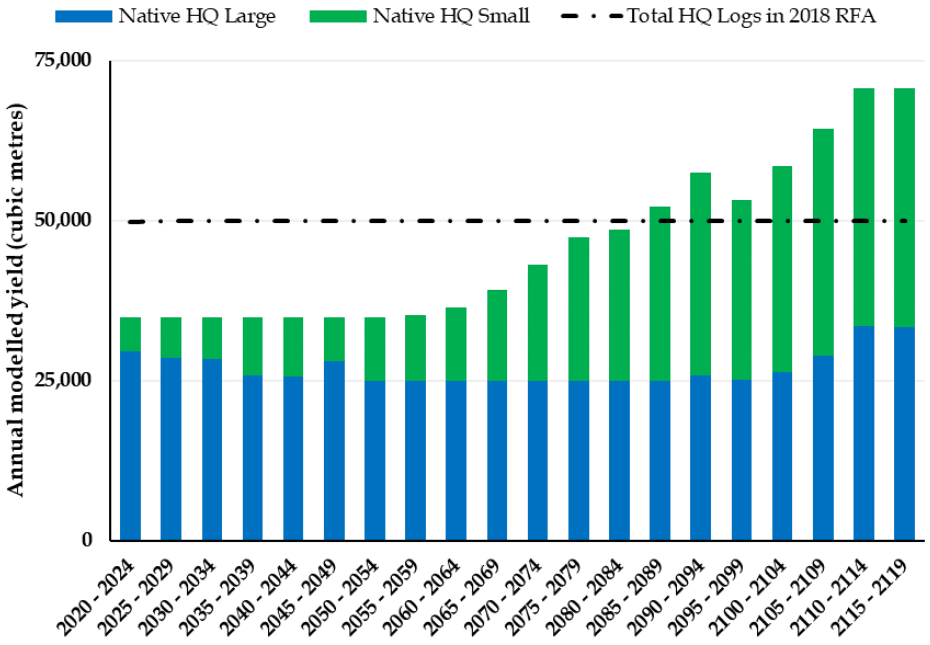

Figure 9: Post-2019/20 wildfires projected HQ[57] wood supply from state forests for the South Coast subregion compared to pre-fire long-term projected sustainable yield

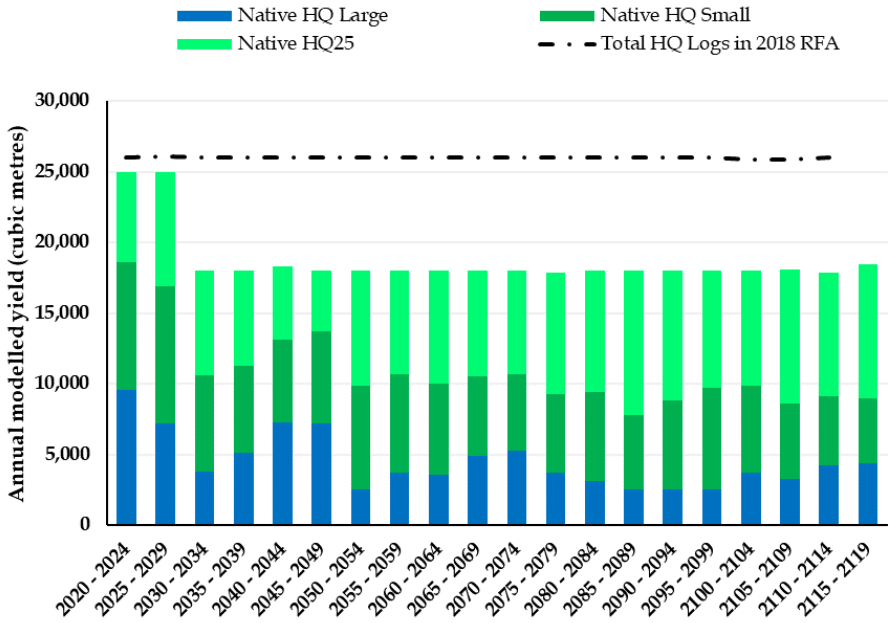

Figure 10: Post-2019/20 wildfires projected HQ[58] wood supply from state forests for the Eden subregion compared to pre-fire long-term projected sustainable yield

57 'Total HQ Logs in 2018 RFA' represents the sum of all projected HQ log classes in modelling used for the 2018 Regional Forest Agreement review. Some models were updated for that review, while others used earlier projections (e.g. Tumut had not been updated since 2009).

58 HQ25 is an additional HQ small grade in the Eden subregion for logs meeting FCNSW's log specifications for HQS, including a centre diameter under bark of equal or greater than 25 centimetres.

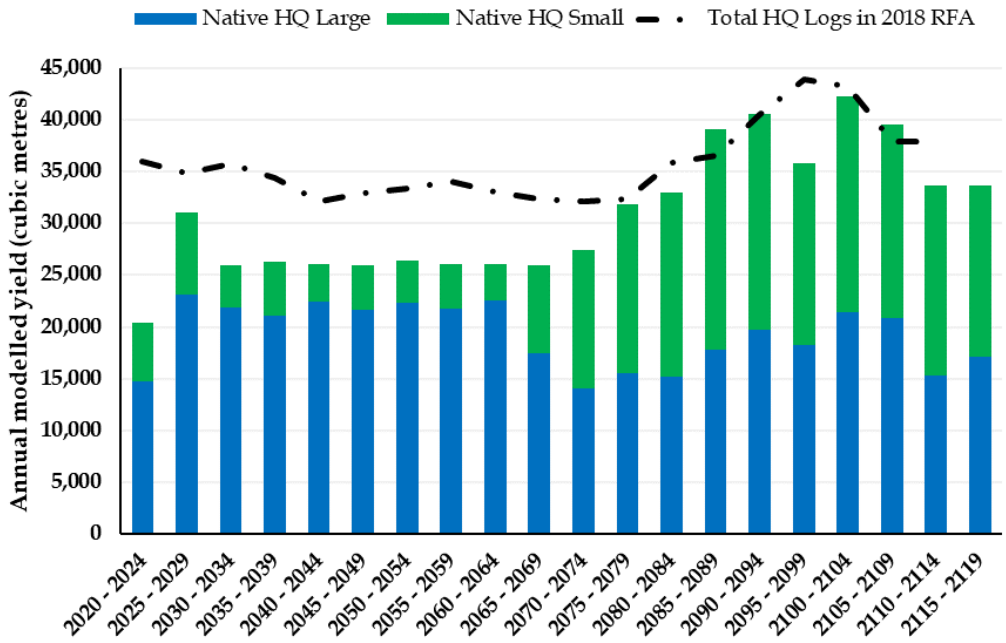

Figure 11: Post-2019/20 wildfires projected HQ wood supply from state forests for the Tumut subregion compared to pre-fire long-term projected sustainable yield

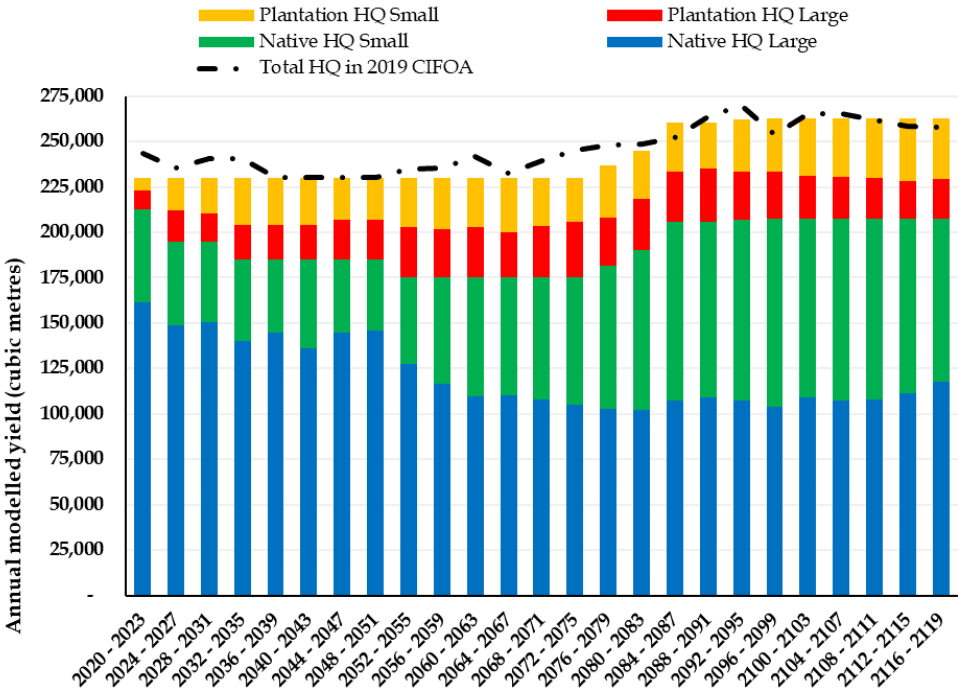

Figure 12: Post-2019/20 wildfires projected HQ wood supply from state forest for the North Coast compared to pre-fire long-term projected sustainable yield

Revising sustainable yield estimates

The Commission considers there are some limitations to long-term sustainable yield projections due to uncertainty associated with future climate impacts on forest growth and changes to fire and drought frequency and severity. FRAMES does not incorporate climate change into yield projections. However, FCNSW is working with the Bureau of Meteorology to relate historical climate and forest growth to better understand climatic influences on the empirical growth and yield models used in FRAMES as part of ongoing improvements. The Commission recommends the NSW Government support FCNSW to accelerate this work to support the implementation of the pathways if they are adopted by the NSW Government. This work should also be subject to robust independent review.

The Commission also recommends that a that additional funding is provided to enable FCNSW to accelerate its sustainable yield modelling improvement program to incorporate projected changes in climate and fire regimes and post-fire mortality and growth assumptions. This should allow multiple scenarios to be explored to understand the base case, the 2019/20 wildfire impacts on the available resource, and to run sensitivity analyses on potential climate change impacts (including frequency, extent and severity of future wildfires) going forward. This will likely require FCNSW to invest in additional modelling resources.

FRAMES has been an effective tool for strategic decision-making but could be strengthened by investment in a spatially based wood supply yield modelling platform that can provide data on landscape and operational scale wood supply and efficiently estimate the impacts of large-scale stochastic events such as fire or other disturbances, as well as climate change scenarios.

4 Giving effect to the pathways

This chapter outlines several factors that should be considered to ensure the successful implementation of the recommended pathways, as well as improve the ongoing management of large-scale threats to the state forest estate. These include:

- the development of a new condition and associated protocol(s) in the Coastal IFOA to manage *force majeure* events (**Section 4.1**)
- proposed interim arrangements ahead of a new condition and protocol being approved (**Section 4.2**)
- updating data on forest recovery to inform the assessment (**Section 4.3**)
- adopting an adaptive management approach to continuously improve the framework (**Section 4.4**)
- improving the evidence base for forest management longer-term, specifically around the impacts of large extent fires (**Section 4.5**)
- roles and responsibilities for implementation (**Section 4.6**).

4.1 A new condition and protocol should be added to the Coastal IFOA

The terms of reference states that the Commission's review will inform the responsible Ministers on a recommended way to give effect to the advice of the Commission to manage forestry operations in fire-affected forests following the 2019/20 wildfires. It also asks the Commission to recommend best practice approaches to manage forestry operations in fire-affected forests to satisfy the purposes of Part 5B of the *Forestry Act 2012* and the objectives and outcomes of the Coastal IFOA.

The purpose of Part 5B of the *Forestry Act 2012* is to authorise the carrying out of forestry operations in accordance with the principles of ESFM and to integrate the regulatory regime for various environmental and threatened species law. A key element of the principles of ESFM is to ensure accountability and transparency in relation to the carrying out of forestry operations.

The Commission considers its advice should be given legal standing to best meet the objectives of the *Forestry Act 2012* and the principles of ESFM (and the request under the terms of reference). This would ensure FCNSW has a clear rule set to comply with, and EPA to regulate against. Communities would also benefit by having a transparent ruleset in place.

The Commission also considers the risks associated with forestry operations in a severely fire-affected landscape are considerably higher than existed prior to the 2019/20 wildfires, and this situation warrants legally enforceable measures that can be regulated.

To achieve legally enforceable measures that can be regulated either requires SSOCs or amendment of the Coastal IFOA to incorporate a new condition and protocol. The Commission considers a new condition and protocol is the optimal approach to managing forestry operations after large-scale wildfires, including the 2019/20 wildfires or a future similar event. The following sections outline the Commission's suggested approach to include a new condition and protocol, alternative approaches, and the associated benefits and disbenefits.

Recommended framing of a new condition

The recommended pathways and risk assessment framework described in this report have been developed in response to a *force majeure* event. A *force majeure* is an unforeseeable circumstance that prevents a party from fulfilling obligations under an agreement.[59] This concept is commonly applied under law to provide clarity around an agreed alternative arrangement if such an event occurs. In this context, the 2019/20 wildfires were an unforeseeable event that have impacted FCNSW's ability to meet the objectives and outcomes of the Coastal IFOA if harvesting were to proceed under standard prescriptions.

The pathways and risk assessment framework are intended to provide a repeatable and transparent process to manage risks around forestry in fire-affected areas after major wildfires.

Implementing these recommendations would require parties to apply additional measures as well as the standard Coastal IFOA prescriptions. Other than as allowed for under SSOCs, there is no condition in the Coastal IFOA that enables the NSW Government or an agency to suspend the Coastal IFOA in part or full if a *force majeure* event occurs, and apply alternative measures across the Coastal IFOA region. While Section 69R[60] of the *Forestry Act 2012* allows for the Ministers to suspend the Coastal IFOA, it is not clear that such a suspension could be used to apply different prescriptions during a suspension.

To give effect to the pathways, a new condition and protocol should be developed and included in the Coastal IFOA. Evidence indicates that large-extent wildfires like the ones experienced in 2019/20 are likely to increase in the future.[61] Establishing a new condition and protocol will ensure the NSW Government can provide effective regulatory responses to *force majeure* events in the future and greater certainty to the timber industry on what may happen after an unforeseeable circumstance.

In the event of a *force majeure*, this new condition would give Ministers a transparent and repeatable tool to temporarily implement additional requirements for forestry operations in impacted areas as needed. The Commission acknowledges that developing and implementing the new condition and protocol will take time and require significant consideration, and legal and policy resources. The Commission has recommended interim measures to allow for the implementation of the framework and pathways while the condition and protocol are developed.

---

59 Thomson Reuters (2021) *Practical Law – Force majeure*. Available at: https://uk.practicallaw.thomsonreuters.com/3-107-.5776?transitionType=Default&contextData=(sc.Default)&firstPage=true.

60 Section 69R *Forestry Act 2012*: Revocation, suspension or amendment of approval
(1) An integrated forestry operations approval may be amended, suspended or revoked at any time jointly by the Ministers authorised to grant the approval.
(2) (Repealed)
(3) A suspension of the approval may extend to all or any of the forestry operations covered by the approval.

61 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H. and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16:044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.

EPA and DPI should have joint responsibility to develop and approve the protocol to support the new condition

This condition should refer to a new protocol that allows for the application of additional measures and a process to reassess risks associated with the potential cumulative impacts of forestry in severely fire-affected or disturbed areas. The EPA and FCNSW should also be given allowance to request a *force majeure* be considered by the Ministers, with Ministers required to respond within 14 days. If this approach were to be adopted, it would set clear roles and responsibilities for the EPA and FCNSW to assess impacts, apply appropriate mitigations, monitor forest recovery and guide compliance activities.

A new condition is recommended rather than amending an existing condition, as amendments to the Coastal IFOA should not be made that change the original intent of a condition. This would occur if an existing condition was changed to refer to a new protocol covering large extent wildfires or other *force majeure* events.

Under Section 69R of the *Forestry Act 2012*, the Ministers can jointly amend, suspend or revoke an approval at any time. This section could be used to amend the Coastal IFOA to include the recommended new condition. However, proposed amendments require public consultation of at least 28 days under Section 69RA of the *Forestry Act 2012*. The Commission notes that, while the Minister can consider if consultation is unnecessary if the amendment is of a minor nature, such an amendment and the implications of it are significant and warrant public consultation in line with Section 69L(2)(b) under Part 5B of the *Forestry Act 2012*.

Under Section 69P of the *Forestry Act 2012*, an approval can apply or adopt protocols, codes, standards or other instruments. These protocols can be prepared by the EPA and are not subject to joint granting by the Ministers. The EPA is not required to involve or consult other parties in the preparation of protocols.

However, the Commission considers that any new protocol for harvesting in severely fire-affected forests should be prepared by the EPA in close collaboration with FCNSW and jointly approved by the Chief Executive Officer of the EPA and Director General of DPI. The protocol referred to by the new condition could be expanded and amended periodically in consultation with FCNSW to accommodate different types of *force majeure* events as knowledge of threats improves.

There are also two alternative approaches that could be adopted instead of a new condition and protocol. The first would be to adopt the approach applied after the 2019/20 wildfires by applying SSOCs under Condition 23.4 of the Coastal IFOA. However, the Commission does not consider this the most effective approach to ongoing implementation. While the use of SSOCs in selected areas was agreed to by the EPA and FCNSW as an interim approach following the 2019/20 wildfires, it was not intended to be a long-term solution for the ongoing management of risks from forestry in severely fire-affected areas.

While the SSOCs increase protections to address key post-fire harvesting risks (such as reducing harvesting intensity and including buffers on exclusions), SSOCs were only meant to be applied at a site-scale and on a case-by-case basis. Condition 23.4 of the Coastal IFOA was not designed to address multi-scale impacts and risks of such a significant magnitude. Further the SSOCs

issued post 2019/20 wildfires only apply for a period of 12 months, which may not capture the recovery period for certain forest types or forest dependent species.[62]
In addition, SSOCs are likely to be relatively less efficient and effective for managing large-scale events. Each SSOC must be negotiated on a case-by-case basis, creating delays and uncertainty for the timber industry. While the EPA and FCNSW continued to negotiate new SSOCs, none were issued after May 2020. Noting that the existing SSOCs were developed by the EPA and FCNSW through a negotiation process, of the 20 SSOCs that were issued, operations have only been completed in half of these. Further, FCNSW advised that operations will not be undertaken under six SSOCs due to a lack of viable timber remaining after applying the conditions (for example, Bungawalbin, Doubleduke, Girard and Collombatti state forests) or because there is an unacceptable compliance risk (for example, Myrtle State Forest).[63] There are no provisions within SSOCs to amend them as new information comes to hand, which means if one condition is no longer relevant the SSOC would need to be revoked and reissued.

It is also unclear if SSOCs will achieve forest regeneration outcomes under the Coastal IFOA, including ecological and wood supply outcomes. FCNSW staff raised concerns regarding some tree retention requirements in the SSOCs, including that the conditions result in trees being retained that have limited ecological value and the recovering crowns of these trees will shade regenerating seedlings suppressing growth and compromising potential future high-quality wood supply.

Importantly, SSOCs can only be triggered by FCNSW at its own discretion. There are two situations under Condition 23.4 where FCNSW can trigger the preparation of SSOCs. The first is if FCNSW consider that applying a condition at a specific site would result in a poor environmental outcome. The second is if FCNSW consider that in a specific and unique circumstance it would not be able to comply with the conditions of the Coastal IFOA. However, the EPA is under no obligation to grant a SSOC. Having a *force majeure* condition and associated protocol would provide clarity to the EPA and FCNSW on appropriate conditions and requirements in response to significant, large scale events and to provide greater certainty for the timber industry that forestry operations could continue albeit under reduced supply.

The second alternative approach to adopting a new condition and protocol would involve FCNSW implementing the additional measures under a voluntary arrangement. However, the EPA does not have authority to regulate or enforce voluntary measures as they sit outside the Coastal IFOA conditions and protocols.[64] Under a voluntary arrangement, implementation of the approach could be unclear, unless it was supported by detailed documentation outlining resourcing, agency roles and responsibilities, and what to do if FCNSW or other agencies do not fulfil their voluntary obligations. However, the Commission notes that FCNSW has the authority to impose penalties for breaches to harvesting plan requirements as issued to harvesting contractors.[65]

---

62 Noting that some conditions extend beyond the duration of SSOCs, such as management actions associated with dieback, regeneration risks or biosecurity risks, and monitoring and reporting.

63 Information supplied by FCNSW 18 May 2021 on the status of SSOCs as at February 2021 (noting the status has not changed since then).

64 EPA (2020) *Update on forestry operations and regulatory activities*. Available at: https://www.epa.nsw.gov.au/your-environment/native-forestry/bushfire-affected-forestry-operations/update-february-2021.

65 Under Section 11(1)(a) of the *Forestry Act 2012*, one of the principal functions of FCNSW is to carry out or authorise the carrying out of forestry operations in accordance with good forestry practices on Crown-timber land. Further, under Clause 34 of the *Forestry Regulation 2012*, timber harvesting contractors are required to hold a contractor licence to operate on state forest (or crown lands). The contractor licenses require that the

4.2 Interim arrangements should be implemented now

Agencies advised that a new condition and protocol will likely take at least 12 months to develop, conduct public consultation and submit to Ministers to consider and approve. However, there is an urgent need to provide greater certainty to the timber industry, the regional communities dependent on this industry and to provide greater environmental protections over what the Coastal IFOA currently provides for. In addition, FCNSW and EPA would benefit from additional time to test and understand the practical implications associated with implementing gateways 2 and 3 in the risk assessment.

To address these concerns the Commission recommends the following interim arrangements be adopted while the NSW Government develops the associated recommended condition and protocol:

- FCNSW can commence new forestry operations under standard Coastal IFOA prescriptions in management zones classified by the Commission as low risk (and continue any existing forestry operations in low risk areas)
- jointly under Section 69R of the *Forestry Act 2012*, the two Ministers suspend existing, planned or new forestry operations in management zones classified by the Commission as extreme risk until a new condition and protocol is adopted[66] (existing operations should cease as soon as operationally practical but no longer than three months)
- the NSW Government request in writing that FCNSW:
    - continues with existing forestry operations under SSOCs or the Coastal IFOA with FCNSW's additional supplementary measures in management zones classified by the Commission as medium or high risk, but harvesting in these operations must cease within six months, after which interim arrangements must be voluntarily adopted (described in the following point)
    - for all other forestry operations, adopt on a voluntary basis the risk assessment process, including fieldwork, and additional measures for planned or new forestry operations in management zones classified as medium and high risk, and apply until a new condition and protocol is adopted
- the Commission oversees the interim arrangements in close collaboration with FCNSW and EPA and provides any further advice to the NSW Government on the recommended condition and protocol before finalising.

The Commission notes these interim arrangements would be implemented voluntarily for a short period while the condition and protocol are put in place. This would mean that the EPA would not have authority to regulate compliance against the additional measures. However, this arrangement is consistent with the ESFM principles set out in Section 69L(2)(c) of the *Forestry Act 2012*, which provide for incentives for voluntary compliance, capacity building and adoption of best practice standards. Further, FCNSW has functions under the *Forestry Act 2012* to carry out and authorise the carrying out of forestry operations on Crown-timber land and to authorise and enforce harvesting contractor licences in accordance with harvesting plans issued

operator must comply with the conditions of the harvest plan. FCNSW uses this mechanism to impose penalties on contractors for breaches of IFOAs as well as harvest plans.

66 The Commission notes that under obligations intended to be legally enforceable in the NSW Regional Forest Agreements, NSW is required to advise the Commonwealth within 14 days of a termination, suspension or revocation of an integrated forestry operations approval that applies in a Regional Forest Agreement area.

to them.[67] This provides a legally enforceable mechanism to ensure the additional measures are being addressed in harvesting operations.

4.3 Recovery data needs to be ground verified and used in decision making

The risk assessment is designed to consider forest recovery. Up to 22 months has passed since the wildfires. In this time, NSW has seen a significant shift in rainfall patterns compared with the drought conditions that preceded the wildfire season. The shift in rainfall patterns to wetter conditions has coincided with a La Niña event between October 2020 and March 2021.[68] In 2020, rainfall was 14 percent above average for NSW, which is nearly as much as 2018 and 2019 combined. There was particularly heavy rain in coastal regions in February 2020, as well as in December 2020 in north-east NSW.[69]

Above average rainfall patterns continued across much of NSW in early 2021, with NSW recording the wettest summer since 2011/12 (29 percent above the 1961-1990 average).[70] Extreme rainfall and significant flooding affected many coastal areas in March 2021, with NSW experiencing its second-wettest day, second-wettest March, and third wettest week on record since 1900.[71]

This rainfall has likely had a positive impact on forest recovery, with photo points in many Coastal IFOA areas showing significant forest recovery (see for example **Figure 22** in **Section 6.2,** which shows a series of permanent photo point data). This recovery is not captured in the FESM version 3 data, as FESM only provides a point in time snapshot of the extent and severity of the 2019/20 wildfires.

Remote-sensing scientists from DPIE-EES and DPI Forest Science have developed a post-fire spectral recovery index to estimate vegetation recovery since the 2019/20 wildfires.[72] It uses satellite imagery to compare pre- and post-fire normalised burn ratio[73] values. Similar to previous studies, where values meet or exceed 80 percent of the pre-fire normalised burn ratio value, the Commission has used this to indicate a strong return of vegetation, including canopy,

---

67 Under Section 11(1)(a) of the *Forestry Act 2012*, one of the principal functions of FCNSW is to carry out or authorise the carrying out of forestry operations in accordance with good forestry practices on Crown-timber land. Further, under Clause 34 of the *Forestry Regulation 2012*, timber harvesting contractors are required to hold a contractor licence to operate on state forest (or crown lands). The contractor licenses require that the operator must comply with the conditions of the harvest plan. FCNSW uses this mechanism to impose penalties on contractors for breaches of IFOAs as well as harvest plans.

68 Australian Bureau of Meteorology (2021) *ENSO Outlook*. Available at: http://www.bom.gov.au/climate/enso/outlook/.

69 Australian Bureau of Meteorology (2021) *New South Wales in 2020: above average temperature and rainfall*. Available at: Australian Bureau of Meteorology (2021).

70 Australian Bureau of Meteorology (2021) *New South Wales in summer 2020-21: wet and cool*. Available at: http://www.bom.gov.au/climate/current/season/nsw/summary.shtml.

71 Australian Bureau of Meteorology (2021) *Special climate statement 74 – extreme rainfall and flooding in eastern and central Australia in March 2021*. Available at: http://www.bom.gov.au/climate/current/statements/scs74.pdf.

72 Gibson, K.R. and Hislop, S. (MS) *Signs of resilience in resprouting Eucalyptus forests, but areas of concern: One year of post-fire recovery from Australia's Black Summer 0f 2019-20*. Submitted to PNAS.

73 The normalised burn ratio has demonstrated capabilities in characterising post-fire forest dynamics. See for example, Gibson, R. *et al.* (2020) 'A remote sensing approach to mapping fire severity in south-eastern Australia using sentinel 2 and random forest'. *Remote Sensing of Environment*, 240(111702); Shvetsov, E.G. *et al.* (2019) 'Assessment of post-fire vegetation recovery in Southern Siberia using remote sensing observations'. *Environmental Research Letters*, 14:055001.

but acknowledge that it does not necessarily indicate a return to the same forest conditions that existed at a site prior to disturbance.[74]

The Commission acknowledges the extended period of drought immediately prior to the wildfires and the influence this may have on the pre-fire spectral values. The observed differences in spectral imagery pre- and post-fires may be picking up recovery of vegetation related to the impacts of prolonged drought conditions as well as the wildfires. Further, where the spectral recovery shows strong vegetation recovery, this may only be associated with understorey and not canopy, or it may be both understorey and canopy. Ahead of further development work, the Commission has adopted a conservative and limited application of the recovery index in recognition that it does not currently differentiate between understorey and canopy recovery and has uncertain application as an indicator of ecological recovery at this point in time. Where the spectral recovery index is applied in the Commission's approach (gateways 2 and 3), the remote sensing observations must be validated by on-ground assessment.

For the application of the recovery index at gateways 2 and 3, strong vegetation recovery is taken to have occurred where the spectral recovery index is in the range 80 percent to 99 percent. Values at or above 100 percent have been excluded from the initial assessment as, in some areas, values greater than 100 percent may represent groundcover regeneration flush and not recovery of canopy species. This assumption may exclude areas that have had strong vegetation recovery, including canopy. After further development and field validation work, the recovery index threshold could include all values that meet or exceed 80 percent, including values at or above 100 percent.

The Commission has confidence in the proposed application of the recovery index based on field observations by suitably qualified staff during this review. However, further work remains to validate the spectral recovery index and ensure the accuracy and reliability of remotely sensed observations to indicate ecosystem recovery.

To collect the necessary data to: 1) validate the recovery from the current version of the post-fire spectral recovery index and 2) develop future versions of the index that captures additional forest measures (such as forest structure or above ground biomass) two on-ground data collection methods will be used:

- A rapid assessment to relate field measures of cover to satellite-derived products as part of the Gateway 3 assessment (**Section 5.4**)
- terrestrial laser scanner monitoring plots to provide the more detailed measurements of sub-canopy structural change that will be used as part of the Coastal IFOA monitoring program.[75]

As noted in **Section 5.1**, the Commission considers the use of FESM only at the management zone scale is correct for the initial baseline assessment of impacts and does not support the use of the post-fire spectral recovery index at the management zone scale at this point in its development without extensive field validation.

Part of this validation will occur during the Gateway 3 assessment at the local landscape area, as FCNSW must ground validate canopy recovery and confirm groundcover has recovered to

74 White, J.C. *et al.* (2017) 'A nationwide annual characterization of 25 years of forest disturbance and recovery for Canada using Landsat time series'. *Remote Sensing of Environment*. 194: 303-321.

75 Further information can be found at: https://www.nrc.nsw.gov.au/ifoa-mer-forest-health.

the designated threshold. To further support ground validation, the NSW Government should also concurrently establish a rigorous, large-scale, scientific field sampling program across the Coastal IFOA region.

Following this, researchers intend to undertake further development work on the post-fire spectral recovery index. This will include better understanding how FESM severity classes can be used to differentiate where the recovery response observed is occurring in the forest structure (for example, where low severity fire occurred the observed recovery will be below the canopy). This will produce an enhanced product for future assessments, which can be used to consider implications from future fires. There is also the opportunity for the recovery index to be supplemented with aerial photography and airborne high-density light detection and ranging (LiDAR) imaging.

DPIE-EES estimates that it will cost around $750,000 over the next three years to develop a fully ground-validated and operational recovery model with fully integrated FESM mapping. This funding would include technical specialist salaries, fieldwork expenses, and data and modelling infrastructure. The Commission is confident the model can support decision making in the current risk assessment if appropriate ground validation is in place and accelerated.

A more accurate forest recovery index would have other uses, including estimating and tracking recovery after future fires and may be useful for considering impacts of other forest disturbances such as dieback or drought.

4.4 The framework should be checked regularly and adaptively managed

The risk assessment framework developed to determine the pathways is based on best available evidence and expert judgement. The Commission is confident that the proposed framework is fit-for-purpose and has built in several mechanisms – including multi-scale risk assessments, field tests and EPA sign off requirements for harvest planning – to reduce the risk of errors or perverse assessment outcomes.

However, like most management processes, uncertainties will always remain, particularly in the setting of risk thresholds and use of remotely sensed data. It is not possible to test the appropriateness of all elements of the framework in all possible situations. It is therefore critical that an adaptive management approach is adopted, with mechanisms allowing for regular review and improvement of the framework as lessons are learned through its implementation.

The Commission recommends that adaptive management of the framework is facilitated through the existing Coastal IFOA annual health check process. This process was established to identify where Coastal IFOA settings can be improved using multiple lines of evidence and key lessons from implementation. The annual health check is also linked to the Coastal IFOA monitoring and research program, which should be used to inform improvement of the framework and pathways (see **Section 3.5**).

The process already involves the key parties responsible for the implementation of the framework (the Commission, EPA, FCNSW, DPI Forestry and DPIE-EES), as well as independent experts.

4.5 A stronger evidence base is needed for forest management long-term

The NSW Government has supported forest research for many years and has built up substantial knowledge and datasets. For example:

- the DPI Forest Science group leads research in forest carbon (such as life cycle assessments), ecology (such as koala research), health (such as mapping pests and diseases), and resources (such as growth modelling)
- the DPIE Science, Economics and Insight Division deliver research in forest-related matters such as climate science, remote sensing and landscape science, conservation and restoration, and advanced analytics and economics.

The Commission is independently overseeing a monitoring program with the NSW Forest Monitoring Steering Committee to measure the ongoing effectiveness of the Coastal IFOA in achieving its objectives and outcomes.[76] This program forms part of the wider NSW Forest Monitoring and Improvement Program under the Premier's terms of reference, and will lead and coordinate monitoring, evaluation and research for improved forest management on public and private land.

The design and implementation of monitoring will remain adaptive during the recovery of the forests to ensure the program can monitor Coastal IFOA prescriptions and ensure they continue to meet outcomes. It is critical that monitoring programs continue to be adequately resourced to address knowledge gaps.

There is also significant opportunity to learn from the current situation by undertaking targeted research on forestry and forest management in fire-affected areas to improve management in the future. For example, the Oregon Department of State Lands and the Oregon State University have recently initiated a large-scale experiment to investigate the impacts of forestry in Oregon, USA. The approach aims to test several forest management strategies including extensive harvesting.[77]

While the work underway will support implementation of the pathways if adopted, the scope and scale of some of this work will need to be expanded, including targeted, experimental research to understand if and how forestry can occur in future post-fire landscapes. This information is critical to support implementation of the pathways, as well as to inform policies and responses to future large-scale fire complexes.

Decision-making in this area will always rely on judgement and expert advice to some extent. However, the NSW Government should invest in tailored information to support future data-driven decision making. This will help reduce uncertainty and increase confidence in 'what to do next' when future fires impact forests and the forestry sector.

76 As required under Protocol 38 of the Coastal IFOA.

77 State of Oregon (2021) *Exploring an Elliot State Research Forest*. Available at: https://www.oregon.gov/dsl/Land/Pages/Elliott.aspx#:~:text=The%20Elliott%20State%20Forest%20was%20established%20northeast%20of,and%20managed%20by%20the%20Department%20of%20State%20Lands.

The Commission has identified additional monitoring and research needs, over and above the work underway, including:[78]

- considering climate change in harvest planning and monitoring
- minimum threshold of disturbed forest and ecosystem legacies to retain in post-fire harvesting operations
- verification of responses of key plant species across the full spectrum of patterns of fire frequency and fire threshold categories
- viability of fauna populations within areas burnt by high or extreme severity in 2019/20, areas harvested since 2000 then burnt in 2019/20 and, the high-frequency wildfire 'hotspots'
- recovery rates of species in response to the amount and configuration of mature forest in both post-fire and post-fire harvested landscapes
- short fire-intervals on slower post-fire spectral recovery rates in temperate eucalyptus forests and woodlands and whether this indicates a decline in ecosystem resilience
- the influence of severe pre- and post-fire drought conditions on the rate of post-fire response and potential decline of ecosystem resilience
- the post-fire spectral recovery rate following the 2019/20 fires in the Australian Alps compared to recovery rates following historical fires in the region
- investigating and testing spectral forest recovery indices to define the pre-fire forest stand state and predicted years to recovery - includes testing of modelling historical patterns of fire severity to inform the development of potential metrics of ecological resilience
- riparian buffer widths and the long-term influence of different widths on fauna occurrence and recovery rates in disturbed areas, and interception of sediment
- post-fire groundcover vegetation recovery to track recovery of sedimentation rates to pre-disturbance levels
- the connectivity of runoff from compacted roads and tracks with the natural streams in the post fire period
- long-term forest productivity and health in post-fire harvested forests and its impact on wood flows and environmental values
- the impacts and implications of different types and intensities of harvesting operations and other active interventions in the burnt landscape and monitor how the forest responds.

Good practice suggests knowledge gaps should be addressed using an active adaptive management framework where learning is a key outcome – not just monitoring and research itself.[79] Such an approach is not about incremental improvement based on observations, but about intervening purposefully to obtain new information and insights.[80]

78 Informed by the literature review, advice from the expert panel and advice to the Commission on risks to the Coastal IFOA posed by the 2019/20 fire season and beyond.

79 Parma, A., Amarasekare, P., Mangel, M., Moore, J., Murdoch, W., Nooburg, E., Pascual, A., Possingham, P., Shea, K., Wilcox, C. and Yu, D. (1998) 'What can adaptive management do for our fish, forests, food and biodiversity?' *Integrative Biology, Issues, News and Reviews*, 1(1):16–26.

80 Stankey, G., Clark, R. and Bormann, B. (2005) *Adaptive Management of Natural Resources: Theory, Concepts, and Management Institutions*, Portland, Oregon, United States Department of Agriculture - Forest Service.

This approach would encourage land managers to treat management actions as experiments, drawing on scientific methods to develop and test hypotheses about how different interventions will help achieve stated outcomes.[81] As a practical example, FCNSW could design an approach to scientifically test the outcomes of different harvesting practices and intensities in fire-affected landscapes.

Climate and bushfire modelling predicts these drought and fire conditions will happen again in the future. Ensuring that the NSW Government has the best empirical evidence regarding the impacts of the full range of management prescriptions will allow faster, more targeted, and more effective responses to future bushfires.

4.6 Roles and responsibilities

Chapter 5 outlines the proposed risk assessment framework in detail, including roles and responsibilities for each action. A summary of key roles and responsibilities in implementing the pathways and risk assessment framework is provided below. It is noted that some of these roles are already undertaken as standard Coastal IFOA practices and should continue to follow established processes:

- **Minister for Regional NSW and Minister for Energy and Environment –** jointly approve the new condition.
- **The Commission –** undertakes management zone-scale desktop assessment annually (or more frequently if data allows), providing results to the Ministers, EPA and FCNSW; oversees interim arrangements; continues to oversee burnt area monitoring and the Coastal IFOA monitoring program.
- **NSW Forest Monitoring Steering Committee –** regularly review and improve the risk assessment framework under its oversight role and annual health checks for the Coastal IFOA monitoring program; recommends priority research and monitoring.
- **FCNSW –** voluntarily adopts interim arrangements; runs local landscape area-scale desktop and on-ground assessments, including documenting results and demonstrating how measures are met; continues day-to-day work to comply with the Coastal IFOA; propose amendments to the framework via the Coastal IFOA monitoring program annual health check process. These roles will require additional resourcing including staff.
- **EPA –** collaborates with FCNSW and Commission on interim arrangements; lead development of the new condition and protocol in close collaboration with FCNSW and jointly approves the new protocol with DPI; propose amendments to the framework via the Coastal IFOA monitoring program annual health check process.
- **DPI –** continues to lead forestry policy and fund forest science research and jointly approves the new protocol.
- **DPI Forest Science –** delivers forest science research; improves recovery index to monitor forest recovery in collaboration with DPIE-EES.
- **DPIE-EES –** further development of FESM and improved recovery index to monitor forest recovery, in collaboration with DPI Forest Science. DPIE-EES estimate that it will cost around $750,000 over the next three years to develop a fully ground-validated and operational fire impact and spectral recovery index.

[81] Stankey, G., Bormann, B., Ryan, C., Shindler, B., Sturtevant, V., Clark, R. and Philpot, C. (2003) 'Adaptive management and the Northwest Forest Plan - Rhetoric and reality'. *Journal of Forestry*, 101: 40–46.

Part 2 – The framework used to develop the pathways

5 A risk and evidence-based framework

To determine the recommended pathways, the Commission developed a data-driven, multi-scale risk assessment framework to assess environmental risks. **Figure 3** in **Section 2.1** provides an overview of the risk assessment framework and possible pathways. Broadly, the framework has three gateways:

- **Gateway 1** applies a desktop risk assessment at the management zone scale, using two remote sensing datasets: fire severity at the time of the 2019/20 wildfires (based on DPIE-EES' FESM version 3) and recovery since fires (based on DPIE-EES/DPI's post-fire spectral recovery index). An overview of the datasets used to inform the risk assessment and their current limitations is outlined in **Section 5.1**. Detail on the Gateway 1 assessment is provided in **Section 5.2**.
- **Gateway 2** applies to local landscape areas within management zones that received a medium or high risk rating in Gateway 1. It involves a desktop assessment at the operational scale (local landscape area) using FESM and the post-fire spectral recovery index to plan permanent and temporary retentions and determine if additional measures can be met. RAFIT mapping can be applied where data gaps exist in FESM. Detail on the Gateway 2 assessments is provided in **Section 5.3**.
- **Gateway 3** applies to local landscape areas within management zones that received a medium or high risk rating that have passed Gateway 2. It involves field-based assessments at the compartment scale across the local landscape area including ecological surveys to verify the results of the post-fire spectral recovery index and groundcover recovery in riparian exclusions.

Standard pre-harvest broad area habitat searches and targeted species searches required under the Coastal IFOA are still required and will be conducted after the Gateway 3 field assessment. Detail on the Gateway 2 and Gateway 3 assessments are provided in **Section 5.4**.

A risk-based, multi-scale approach was adopted as it:

- allows for careful evaluation of environmental risks, clearly identifying risks and defining risk thresholds for key environmental values
- allows for a transparent and repeatable risk-weighted assessment and comparison of the likely outcomes of a range of management options
- considers the significant variation in impacts and risks observed from the 2019/20 wildfires and subsequent recovery, focussing additional measures on areas where risks are highest and avoiding unnecessary additional measures where risks are low
- provides for a clear articulation of how the precautionary principle has been applied in the absence of specific evidence on the cumulative impacts of forestry in severely fire-affected NSW forests and landscapes (**Section 1.2** provides an overview of the precautionary principle).

Following the risk assessment, areas are classified as either low risk (green), medium risk (yellow), high risk (amber) or extreme risk (red) to indicate the pathway options for decision makers:

Extreme risk	▪ Management zones that receive an extreme risk rating at Gateway 1 will have all future forestry operations in the management zone suspended for three years – then reassess every 12 months or more frequently if data allows ▪ Local landscape areas that receive an extreme risk rating at gateway 2 or 3 will have forestry operations suspended for at least one year until a subsequent 12 month reassessment at gateways 2 and 3 allows operations to proceed under additional measures or until the management zone receives a low risk rating at Gateway 1
High risk **Medium risk**	▪ Management zones that receive a medium or high risk rating at Gateway 1 move to the Gateway 2 assessment ▪ Local landscape areas that receive medium or high risk ratings at Gateway 2 progress to Gateway 3 ▪ Local landscape areas that receive a medium risk rating at Gateway 3 can have forestry operations commence under the Coastal IFOA with additional measures to provide temporary refuges and protect water quality (additional measures are described in **Section 5.5**) – risk is then reassessed every 12 months or more frequently if data allows ▪ Local landscape areas that receive a high risk rating at Gateway 3 can have highly restricted harvesting to promote regeneration for environmental and future wood supply outcomes (additional measures are described in **Section 5.5**) – risk is then reassessed every 12 months or more frequently if data allows
Low risk	▪ Management zones that receive a low risk rating at Gateway 1 are able to commence forestry operations under standard Coastal IFOA prescriptions without further tests at the local landscape scale – standard Coastal IFOA pre-harvest surveys are required

The three-gateway approach allows for risks to be assessed at multiple scales and across tenures, while also allowing for the results to be assessed in the field. This is important as the 2019/20 wildfires were extensive, resulting in large areas burnt at high and extreme severity across the NSW forest estate, with variation in the rate of recovery across the Coastal IFOA region.

This framework should be adopted and repeated for future assessments and decision making. For medium risk management zones and high and extreme risk management zones that have completed the three-year reassessment period, the reassessment process can be undertaken more frequently than 12 months if available data allows it. **Section 5.6** provides detail on the reassessment approach including the rationale for the three-year reassessment period for high and extreme risk management zones. This framework should be used to manage risks after high and extreme severity wildfires in the future, whether they are large scale or smaller scale fires

with cumulative impact. Impacts from future severe wildfires can be incorporated into the risk assessment using updated fire extent and severity data, as well as recovery data.

Adopting a transparent, enforceable and evidence-based approach to decision making will go some way in building trust with the community who have previously expressed concerns about recent approaches to decision making.[82]

5.1 Datasets used in the risk assessment

There are two key datasets used in the risk assessment framework. These are outlined in the following subsections.

Fire extent and severity mapping (FESM) version 3

This dataset has been produced by DPIE-EES and shows the areas affected by different fire severity classes. The Commission used the available 2019/20 mapping produced using FESM version 3 to assess fire extent and severity in forest[83] at the Coastal IFOA, management zone and local landscape area scales. Early versions of FESM were used for reporting and decision making, including as part of the development of the SSOCs issued by the EPA to FCNSW for forestry operations in fire affected sites.

The term fire intensity is used to describe fire behaviour and the energy that is released from the fire, while fire severity refers to the effects the fire had on the ecosystem, vegetation or loss in biodiversity.[84] **Table 12** describes the fire severity classifications used in the fire extent and severity mapping.[85]

82 Letter from the Environmental Defenders Office to the Chief Executive Office of the EPA dated 28 September 2020, regarding concerns over SSOCs issued to permit harvesting in state forests burned in the 2019/20 wildfires.

83 The forest extent dataset that was used was derived from the Forest Monitoring and Improvement Program.

84 Gibson, R., Danaher, T., Hehir, W. and Collins, L. (2020) A remote sensing approach to mapping fire severity in south-eastern Australia using sentinel 2 and random forest. *Remote Sensing of Environment*. 240:111702. Available at: https://doi.org/10.1016/j.rse.2020.111702; Roff, A. and Aravena, R. (2020) *Australian Google Earth Engine Burnt Area Map: A Rapid, National Approach to Fire Severity – technical report*. Published by the Commonwealth of Australia, Department of Agriculture, Water and the Environment, Canberra. Available at: DOI:10.13140/RG.2.2.13434.52167.

85 DPIE (2020) *DPIE Fire Extent and Severity Mapping FESMv3 Factsheet.* Available at: https://datasets.seed.nsw.gov.au/dataset/f7eb3f73-5831-4cc9-8259-8d1f210214ac/metaexport/html.

Table 12: Description of fire severity classes

Fire severity class (fire extent and severity mapping)	Definition	Percentage foliage fire-affected
Unburnt	Canopy and understorey both unburnt	0 percent canopy and understorey burnt
Low	Burnt understorey with unburnt canopy	>10 percent burnt understorey >90 percent green canopy
Moderate	Partial canopy scorch	20-90 percent canopy scorched
High	Complete canopy scorch (with or without partial canopy consumption)	>90 percent canopy scorched <50 percent canopy consumed
Extreme	Complete canopy consumption	>50 percent biomass consumed

Patterns in fire severity have a greater influence on biodiversity and ecosystem function than area burnt.[86] Intense fire can trigger widespread canopy foliage loss and branch, stem or whole plant mortality, causing substantial changes to ecosystem structure and function.[87] The fire severity class this occurs at depends on the mix of tree species and sizes and their resistance to fire.[88]

Fire regimes that may be of concern in terms of forest regeneration, structure and tree dynamics of the Coastal IFOA are likely to be extremes of frequency and intensity/severity.[89] For most vegetation types across the Coastal IFOA region, impacts on ecosystem structure and function would occur at high to extreme fire severities.[90] One exception to this is rainforest, where moderate to extreme fire severity may have considerable impacts,[91] although there are studies showing resilience of rainforest to severe fire.[92]

Noting this, the high and extreme severity classes in FESM were selected as, for most forest types across the Coastal IFOA, fires in these classes will result in partial or complete canopy consumption and cause substantial changes to ecosystem structure and function.[93]

86 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H. and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16:044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.

87 *Ibid.*

88 *Ibid.*

89 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

90 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H. and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16:044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.

91 *Ibid.*

92 Baker, P.J., Simkin, R., Pappas, N., McLeod, A and, McKenzie, M. (2012) Fire on the mountain: A multi-scale, multi-proxy assessment of the resilience of cool temperate rainforest to fire in Victoria's Central Highlands. In Haberle SG, Bruno D (eds.) *Peopled landscapes: Archaelogical and biogeographic approaches to landscapes*. Australian National University Press. pp 375-391.

93 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H. and Penman, T.D. (2021) The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire. *Environmental Research Letters*, 16:044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e; Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

This dataset informs risk assessment in Gateway 1. FESM is currently considered to be a suitable dataset to assess the impacts of the 2019/20 wildfires, as it has been validated on-ground[94], peer-reviewed and published[95], and is available on a public data portal.[96] This dataset is used to inform gateways 1, 2 and 3. However, it only provides a snapshot of impact directly after the wildfires and does not consider recovery since February 2020.

Post-fire spectral recovery index preliminary version

Changes to ecosystem structure and function that result from high and extreme severity fire are typically temporary. Eucalypt forests dominated by epicormic resprouters, are highly resilient to repeated canopy fires and known to rapidly recover vegetation structure, canopy cover and renewed seedbank.[97] **Section 6.2** outlines on-ground evidence that post-fire recovery is in progress.

The framework intends to use the spectral recovery index to inform gateways 1, 2 and 3. This index will provide data on actual vegetation recovery, but significant on-ground validation is still required. As such, the Commission has not used the dataset in the initial Gateway 1 assessment.

As noted in **Section 2.2**, to allow the use of the index in gateway 2 and 3 assessments and future Gateway 1 reassessments, the Commission is proposing to ground-validate the model at two scales:

- rigorous site assessments by FCNSW trained field staff at Gateway 3 of the risk assessment process
- a rigorous large-scale, scientific sampling program at the management zone scale as a concurrent but separate process. This scientific field validation will be led by DPIE-EES in collaboration with DPI Forest Science and FCNSW using both permanent terrestrial laser scanning monitoring plots and rapid assessment plots, to progress future revisions.

FESM version 3 mapping will provide the baseline of fire impacts from which recovery is tracked. If the post-fire spectral recovery index indicates that an area of forest that experienced high or extreme severity fire (as mapped by FESM version 3) has spectral recovery values that meet or exceed 80 percent and are less than 100 percent recovery to the pre-fire value, then that area is considered to have had a strong return of vegetation, including canopy (noting that on-ground checks will still remain in future assessments). **Section 5.3** further describes the method for using the spectral recovery index alongside FESM to determine the area of mapped high and extreme severity that has not met recovery thresholds.

94 Gibson, R., Mitchell, A., Watson, J., Fisher, A., Hislop, S. and Danaher, T. (2020) S*upporting post-fire ecological resilience and recovery planning in NSW forests. Milestone 2 Progress report*. Available at: https://www.nrc.nsw.gov.au/fmip-baselines-ecosystem-health-projectfe2.

95 Gibson, R., Danaher, T., Hehir, W. and Collins, L. (2020) A remote sensing approach to mapping fire severity in south-eastern Australia using sentinel 2 and random forest. *Remote Sensing of Environment*. 240(111702). Available at: https://doi.org/10.1016/j.rse.2020.111702.

96 NSW Government (2020) *Dataset – Department of Planning, Industry and Environment – Fire Extent and Severity Mapping (FESM)*. Available at: https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm.

97 Collins, L. (2020) Eucalypt forests dominated by epicormic resprouters are resilient to repeated canopy fires. *Journal of Ecology*, 108:310-324.

Other fire mapping products in NSW

The Commission acknowledges there are several other fire mapping datasets in NSW. **Box 3** outlines the available fire mapping products in more detail, including their applicability to this review.

The Commission understands from discussions with FCNSW planning and operations staff that when using FESM and spectral recovery index data at an operational scale (for example, as required in gateways 2 and 3) there are several potential issues in its application, including:

- ground features such as roads, log dumps, tracks or other infrastructure may be incorrectly classified into burn severity classes
- underlying process or data issues such as image selection, cloud impacts, or images not correlating with fire containment dates
- isolated or scattered pixels[98] in the remote sensing data can occur as a result of modelling categorisation process (when records either side of a class are split and similar statistically but are categorised differently) or where very small areas of ground or vegetation occur with different reflectance to surrounding vegetation, although the difference is not a reflection of the broader forest.

FCNSW are likely to identify these issues when planning local landscape areas at Gateway 2 assessment. In these circumstances, FCNSW can:

- apply RAFIT mapping product where data gaps exist in FESM
- 'smooth' using Geographic Information System (GIS) software isolated and scattered pixels in the remote sensing data, including FESM or spectral recovery (the process to 'smooth' pixels using a focal majority approach is outlined in **Appendix 2**).

If these issues occur, FCNSW will identify and document issues with FESM mapping and the results of its local landscape area assessment and make this information available to the EPA as per existing portal and process. FCNSW should notify DPIE-EES of identified errors in the FESM mapping. DPIE-EES should work collaboratively with FCNSW to address identified errors in FESM mapping as part of a continual improvement program.

98 Pixel size in FESM and spectral recovery index mapping is 10 metres by 10 metres.

Box 3 – Fire mapping datasets in NSW

The area affected by fire is described in three ways in NSW: fire ground mapping, burnt area mapping, and fire severity mapping.[99] Further, NSW also has post-fire spectral recovery mapping. Datasets available for these categories are outlined below.

Fire severity mapping

This provides a map of fire severity, including a description of the fire's impacts, such as a burnt understorey and a partially scorched canopy. The map is generated using a semi-automated approach to mapping fire extent and severity through a machine learning framework based on Sentinel 2 satellite imagery.[100] From this, there are two mapping tools for NSW: **FESM** and **RAFIT.**

FESM (Fire Extent and Severity Mapping)

This is produced by DPIE and is currently in version 3 of the framework, with the revised 2019/20 wildfire mapping using the updated version released in December 2020. A FESM version 3 map is produced for each fire event in NSW, as the event stabilises. The 2019/20 wildfires mapping as prepared using a mosaic of satellite imagery over the fire season, which ended around February 2020. FESM version 3 is also being used to retrospectively map fire severity from earlier fire seasons. The mapping product is produced by the random forest algorithm, which has been trained and tested on case study fires. Following the 2019/20 wildfires, several wildfire complexes had high resolution aerial photography captured four to six weeks after the fire. These were used to enhance the FESM training dataset to update the model in July 2020. Based on an independent aerial photographic imagery cross-validation assessment (predicting severity classification of new fires not used to train the model), FESM version 3 accuracy statistics range from 85 to 95 percent for unburnt and extreme severity, and between 60 to 85 percent for low, moderate and high severity. The range of vegetation types and area of the landscape tested in the FESM version 3 accuracy assessment is much greater than in FESM version 2.[101]

FESM version 3 mapping is considered suitable for the Commission's assessment for use as the baseline of the impacts of the 2019/20 wildfires and to monitor the recovery against. FESM version 3 is considered a suitable baseline product, as the algorithm used to model fire severity has been trained using different fire season data and aerial photographic interpretation. Further, FESM has been accepted by the NSW Rural Fire Service as a baseline to begin development of an automated system, [102] the dataset is publicly available via the SEED portal and the method used to develop it has been published.[103] This accuracy assessment indicates the data is appropriate to use at a management zone scale and suggests that on-ground verification is likely required at a local scale. Further development work planned by DPIE-EES, including use of terrestrial laser scanning and on-ground validation plots, will further improve the accuracy of this dataset. In addition, this work is contributing to the development of remote sensed forest recovery index, which would provide valuable information to inform future risk assessment at Gateway 1.

99 Roff, A. and Aravena, R. (2020) *Google Earth Engine Burnt Area Map (GEEBAM) Factsheet (March 23rd, 2020)*. Available at: https://datasets.seed.nsw.gov.au/anzlic_dataset/google-earth-engine-burnt-area-map-geebam/resource/a3f3f1a4-1758-4551-a005-a243fd26ec4b.

100 Gibson, R., Danaher, T., Hehir, W., and Collins, L. (2020). A remote sensing approach to mapping fire severity in south-eastern Australia using sentinel 2 and random forest. *Remote Sensing of Environment,* 240:111702 111702. https://doi.org/10.1016/j.rse.2020.111702

101 DPIE (2020) *DPIE Fire Extent and Severity Mapping FESMv3 Factsheet (December 2020)*. Available at: https://datasets.seed.nsw.gov.au/anzlic_dataset/fire-extent-and-severity-mapping-fesm-2019-20/resource/1ee94f00-6681-410f-af89-14d5bd208eca.

102 *Ibid*.

103 Gibson, R., Danaher, T., Hehir, W., and Collins, L. (2020). A remote sensing approach to mapping fire severity in south-eastern Australia using sentinel 2 and random forest. *Remote Sensing of Environment,* 240:111702 111702. https://doi.org/10.1016/j.rse.2020.111702

RAFIT (Rapid Assessment of Fire Impact on Timber)

This was developed by FCNSW in November 2019 to determine and model the impacts of the 2019/20 wildfires on timber yields from NSW state forests. This custom model was developed in parallel with FESM, which was not available within the timeframe that FCNSW required to begin timber supply analysis. This dataset has been trained using on-ground data across the state forest estate, including georeferenced photos and unmanned aerial vehicle imagery in the various RAFIT severity classes as mapped. On-ground observations by FCNSW staff were also used to calibrate damage levels in the different severity classes and re-checked in follow-up field inspections to iteratively confirm the model's underlying assumptions.[104] However, the EPA did not accept the use of RAFIT during post-fire harvest planning under SSOCs, requiring FCNSW to use FESM. Other NSW agencies are also adopting FESM, such as the Rural Fire Service. From observations of FESM and RAFIT coverage at an operational scale, there are some potential issues with FESM coverage that warrant further investigation by DPIE-EES as the product is further developed. Where these gaps or other potential errors in FESM exist, the RAFIT data is a suitable alternative source to address data gaps.

Post-fire spectral recovery index[105]

The post-fire spectral recovery index is currently being developed by DPIE-EES in collaboration with DPI Forest science. This study presents an early whole-of-landscape assessment of the post-fire recovery trends following the wildfire season of 2019-20. Sentinel 2 satellite imagery is used to compare pre-fire and one-year post-fire normalised burn ratio values. A strong positive trend in the return of vegetation was indicated where post-fire values met or exceeded 80 percent of the pre-fire normalised burn ratio value. Remote sensing provides a viable and cost-effective solution for capturing broad-scale observations of post-fire recovery dynamics. In particular, satellite-derived spectral vegetation indices using short-wave infra-red bands, such as the normalised burn ratio, have demonstrated capabilities in characterising post-fire forest dynamics (for example, fire extent, severity and post-fire recovery). Strong correlations between the normalised burn ratio spectral recovery and field-based measurements of post-fire recovery dynamics have been observed in forest ecosystems.

The research has been submitted to scientific journal for peer review. The expert panel for this review considers it is fit-for-purpose provided it is supported by on-ground validation during the risk assessment process and used with FESM version 3.

Fire ground mapping[106]

Fire ground mapping provides a map of the entire fire ground and is based on daily updates from emergency response teams. The NSW Rural Fire Service's **ICON mapping** (Incident Control Online System) shows areas affected by fire, updated daily on the 'Fires Near Me' website.

Fire ground mapping is not suitable for the Commission's assessment as it does not differentiate between unburnt and burnt areas, nor the severity of the fire, both of which provide critical information for the risk assessment.

Burnt area mapping[107]

DPIE's **GEEBAM** (Google Earth Engine Burnt Area Map) represents the first burnt area mapping following the 2019/20 wildfires. It was developed using a rapid mapping tool that

104 FCNSW (2020) *2019–20 Wildfires NSW Coastal Hardwood Forests Sustainable Yield Review*. Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1299388/fcnsw-sustainable-yield-report-2019-20-wildfires.pdf.

105 Gibson, K.R. and Hislop, S. (MS) *Signs of resilience in resprouting Eucalyptus forests, but areas of concern: One year of post-fire recovery from Australia's Black Summer 0f 2019-20*. Submitted to PNAS.

106 Roff, A. and Aravena, R. (2020) *Google Earth Engine Burnt Area Map (GEEBAM) Factsheet (March 23rd, 2020)*. Available at: https://datasets.seed.nsw.gov.au/anzlic_dataset/google-earth-engine-burnt-area-map-geebam/resource/a3f3f1a4-1758-4551-a005-a243fd26ec4b.

107 *Ibid*.

determines the burnt area and the effect of fire based on how much of the canopy appears affected in satellite imagery. Severity classes were based on vegetation formation and visual interpretation of satellite imagery. While useful for operations during fire seasons and to assist land managers in prioritising recovery activities for flora and fauna shortly after wildfires, GEEBAM was an interim product and there is no field data used, ground truthing or assessment of accuracy.[108, 109] In addition, it has been superseded by the FESM products. As such, it is not suitable for the Commission's risk assessment.

5.2 Gateway 1 assessment

Gateway 1 is a desktop risk assessment conducted at the management zone scale. Overall, this gateway aims to assess if the Coastal IFOA provides effective protections for habitat, species and forest regeneration in a severely fire-affected landscape.

To streamline the risk assessment, the Commission aligned relevant Coastal IFOA outcomes with four risk categories, which are provided in **Table 13**. **Appendix 3** shows the alignment of Coastal IFOA outcomes with these risk categories.

Table 13: Risk statements

Risk statements	Risk categories aligned to Coastal IFOA outcomes
The Coastal IFOA standard prescriptions do not provide effective protections to ecological function and connectivity in timber harvest areas of state forests in a severely fire-affected landscape	Maintain ecological function and habitat connectivity
The Coastal IFOA standard prescriptions do not provide effective retention of feed and habitat trees, including recruitment trees in timber harvest areas of state forests, to support the persistence of species dependent on these resources in a severely fire-affected landscape	Persistence of native species
The Coastal IFOA standard prescriptions do not provide effective forest regeneration of forest-age classes and forest structure in timber harvest areas of state forests for ecological outcomes at multiple scales in a severely fire-affected landscape	Promote forest regeneration and structure
The Coastal IFOA standard prescriptions do not provide effective protection of vegetation and groundcover in riparian zones in timber harvest areas of state forests to protect water quality and aquatic habitat in a severely fire-affected landscape	Protect aquatic habitat and water quality

The Coastal IFOA outcomes aligned to ecological function and connectivity, persistence of native species, and forest regeneration and structure all rely on the presence of adequate environmental features and continued refuge for forest-dependent species in a harvested landscape. The Coastal IFOA was approved on the assumption that the CAR reserve system

108 State of NSW (2020) *NSW Government Data Quality Statement: 15 December 2020*. Available at: https://datasets.seed.nsw.gov.au/dataset/google-earth-engine-burnt-area-map-geebam/resource/data_quality_report/pdf.

109 Roff, A. and Aravena, R. (2020) *Google Earth Engine Burnt Area Map (GEEBAM) Factsheet (March 23rd, 2020)*. Available at: https://datasets.seed.nsw.gov.au/anzlic_dataset/google-earth-engine-burnt-area-map-geebam/resource/a3f3f1a4-1758-4551-a005-a243fd26ec4b.

across tenures maintains adequate habitat in the landscape to minimise the short-term impacts that harvesting at the site scale has on species and their persistence. The risk assessment process is designed to investigate the risks associated with forestry operations in severely fire-affected forests, considering both the fire-affected forest extent and fire-affected forest in the public reserve system.

To consider the level of risk that harvesting in the severely fire-affected landscape could have on these outcomes, the initial Gateway 1 assesses the fire extent and severity of a wildfire – in this instance the 2019/20 wildfires – on the:[110]

- public reserve system (**Box 4**)
- overall forest extent (**Box 5**).

Box 4: The public reserve system

The reserve system used in this assessment is the CAR reserve system on public land in the Coastal IFOA region as at December 2019, established in accordance with the Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia.[111] While the CAR reserve system also includes informal reserves on private land, these have not been considered in the Commission's analysis.

The CAR reserve system used in this review consists of the national park estate and reserved areas in state forest, including forest management zone (FMZ) 1 (flora reserves), FMZ 2 (informal reserves), FMZ 3a and 3b (harvest exclusions and prescriptions) and mapped harvesting exclusions in FMZ 4 (values protected by prescription in the general management zone where harvesting is allowed).[112]

Box 5: Forest extent – developed by the NSW Forest Monitoring and Improvement Program

The NSW Forest Monitoring and Improvement Program has developed a mapped forest extent baseline for NSW as at January 2019.

The definition of 'forest' applied to create this forest extent mapping has been defined as vegetation:

- containing, as a minimum, a mature or potentially mature stand height exceeding 2 metres
- containing stands dominated by trees usually having a single stem
- where the mature or potentially mature stand component comprises 20 percent canopy coverage using a crown projective cover measure
- with a minimum mappable unit of 0.2 hectares (or effectively an area 50 metres by 50 metres)
- relates to the presence of canopy cover at a given point in time.

110 Spectral recovery is considered at future Gateway 1 reassessments.

111 Commonwealth of Australia (1997) *Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia*. A report by the Joint ANZECC / MCFFA National Forest Policy Statement Implementation Sub-committee. Available at: https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/rfa/publications/nat_nac.pdf

112 The forest management zoning system is described in State Forests of NSW (1999) *Managing our forests sustainably: forest management zoning in NSW State Forests*. Available at: https://www.forestrycorporation.com.au/__data/assets/pdf_file/0003/438402/managing-our-forests-sustainably-forest-mgt-zoning-in-nsw-state-forests.pdf. Mapped exclusions are described under Division 3 of the Coastal IFOA Conditions.

Risk assessment

The risk assessment follows a standard risk assessment approach that uses a rating of the consequence of not achieving the Coastal IFOA outcomes if standard prescriptions were to be applied in the severely fire-affected landscape and the likelihood of those consequences occurring. As noted above, the Coastal IFOA was approved on a primary assumption that the CAR reserve system maintains adequate habitat in the landscape to minimise the short-term impacts of harvesting at the site-scale and the persistence of species at multiple scales. If reserved habitat has been severely fire-affected and to a sufficient extent, then the primary assumptions underpinning the Coastal IFOA are unlikely to hold.

Quantitative thresholds for consequence and likelihood have been developed in consultation with the expert panel and agency representatives.

Table 14 provides the matrix used to assign a risk rating to each management zone based on:

1 **Reserve system thresholds (consequence) –** the proportion of forest extent[113] in the public reserve system affected by high and extreme severity fire.[114]

2 **Forest extent thresholds (likelihood) –** the proportion of forest extent[115] affected by high and extreme severity fire.[116]

These thresholds are supported by qualitative statements that explicitly link to the precautionary principle (**Appendix 4**) and are based on the following assumptions:

- **Consequence –** the greater the fire extent across the reserve system, the greater the impact that forestry operations in a severely fire-affected landscape could have (noting that harvesting cannot occur in reserves) as the reserves are no longer functioning as a mitigation to harvesting disturbances as effectively as pre-fire. As noted earlier, this recognises the Coastal IFOA was approved on the assumption that the CAR reserve system across tenures maintains adequate habitat in the landscape to minimise the impacts of harvesting at the site scale and the persistence of species and multiple scales.
- **Likelihood –** the greater the fire extent across the total forest extent, the higher the likelihood of the consequence occurring.

There is no known published literature on thresholds that could be adopted as part of a risk-based assessment for the cumulative impacts of forestry operations in a severely fire-affected landscape. As part of the species risk assessment in the NSW Saving our Species program, the International Union for the Conservation of Nature's (IUCN) criteria for red-listed ecosystems criteria are used to estimate a species long-term viability without management. As such, the risk assessment framework has adopted the IUCN red list criteria and used those red list thresholds for forest extent and reserve system impacts.

The thresholds provided in **Table 14** are based on the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria[117] to determine the likelihood of an outcome,

113 Forest extent as at January 2019, defined and mapped by the NSW Forest Monitoring and Improvement Program (unpublished).
114 High and extreme severity fire as mapped by FESM version 3, released by DPIE in December 2020.
115 Forest extent as at January 2019 as defined and mapped by the NSW Forest Monitoring and Improvement Program (unpublished).
116 High and extreme severity fire as mapped by FESM version 3, released by DPIE in December 2020.
117 Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P (2017) *Guidelines for the application of IUCN Red List of Ecosystems categories and criteria, Version 1.1*. Available at: https://portals.iucn.org/library/sites/library/files/documents/2016-010-v1.1.pdf.

which considers the extent and severity of change. **Appendix 5** lists the criteria and some example thresholds for each from these guidelines.

Table 14: Management zone assessment risk matrix

Likelihood (% forest extent burnt at high and extreme severity)	Consequence (% reserve system burnt at high and extreme severity)				
	Insignificant (<10%)	Minor (10-19%)	Moderate (20-29%)	Major (30-49%)	Catastrophic (>50%)
Almost certain (>50%)	Medium	High	High	Extreme	Extreme
Likely (30-49%)	Medium	Medium	High	High	Extreme
Moderate (20-29%)	Medium	Medium	Medium	High	High
Unlikely (10-19%)	Medium	Medium	Medium	Medium	High
Rare (<10%)	Low	Medium	Medium	Medium	Medium

In the absence of data and evidence on the cumulative impacts of forestry in the areas affected by the 2019/20 wildfires, the Commission has adopted a conservative approach to establish risk assessment thresholds and timing to reassess areas. The IUCN vulnerable[118] criteria for red listed ecosystems has been used to indicate when decision makers should start to become concerned with the status of an ecosystem or species. Where the forest extent and the reserve system has experienced 30 percent or more high and extreme severity fire, this results in a high or extreme risk of severe widespread and local impacts.

The endangered IUCN criteria for red-listed ecosystems[119] have been used to represent catastrophic consequence (i.e. more than 50 percent of the reserve system experienced high and extreme severity fire) causing widespread and irreversible harm, when coupled with an almost certain likelihood (more than 50 percent of the forest extent being similarly affected).

On the lower risk side of the risk matrix, the medium risk threshold is set at over and above 10 percent, which reflects the upper extents of pre-2019/20 fire seasons.[120] Below 10 percent represents what could be expected in a normal fire season. The risk ratings in the matrix are then assigned a risk rating that determines the broad pathway (**Table 15**).

118 The IUCN 'vulnerable' category is a category containing species possessing a high risk of extinction due to rapid population declines of 30 to more than 50 percent over the previous 10 years (or three generations), a current population size of fewer than 1,000 individuals, or other factors (*Ibid*).

119 The IUCN 'endangered' category is a category containing species possessing a very high risk of extinction due to rapid population declines of 50 to more than 70 percent over the previous 10 years (or three generations), a current population size of fewer than 250 individuals, or other factors (*Ibid*).

120 This is derived from wildfire disturbance trends generated through the NSW Forest Monitoring and Improvement Program (unpublished).

Importantly, these thresholds should not be set without the ability to adjust them when improved data and other evidence is available. As the forests recover or if future large-scale severe fires occur, research and monitoring will be critical to inform the appropriateness of these thresholds.

Table 15: Alignment of risk matrix to risk assessment

Risk classification	Responses
Extreme	**Uncertainty that impact cannot be confidently mitigated or controlled; potential severe or irreversible damage; avoid risks in the short to medium term; apply the precautionary principle** Forestry operations should not commence for a minimum of three years after the wildfires to allow time for recovery of some ecological functions, such as flowering, and then reassessed annually until a lower risk rating confirmed
High	**Impact to be managed by new condition and protocols** Impact can likely be controlled by additional measures with significant additional retention and heavily restricted commercial harvesting operations Forestry operations are limited for a minimum of three years to allow time for the recovery of some ecological functions, such as flowering, and then reassessed annually until a lower risk rating confirmed
Medium	**Impact to be managed by new condition and protocols** Impact can likely be controlled by additional measures, specific to the impacts at the local landscape area
Low	**Impact in line with historical experience** Impact can be managed by Coastal IFOA prescriptions Impact unlikely to require additional measures to control

For high and extreme risk management zones, a reassessment will not take place until a minimum of three years since the end of the wildfires have elapsed (further information on the reassessment process is provided in **Section 5.6**). This means harvesting will be suspended in management zones assessed as extreme risk for at least three years and in high risk zones harvesting will be heavily restricted for at least three years. This recovery period will allow more time for recovery of some of the ecological functions, such as flowering of the canopy species, that are required to support the persistence of many forest dependent species. For example, some studies have found that resprouting tree species (which included eucalyptus species) take three years (36 months) on average to flower post-fire.[121, 122] Eucalypt nectar and pollen provide important food resources for many forest-dependent species, such as the threatened swift parrot.[123] In addition, fauna species may take anywhere from months to years

121 Burrows, N.D., Wardell-Johnson, G., and Ward, B. (2008) 'Post-fire juvenile period of plants in south-west Australia forests and implications for fire management'. *Journal of the Royal Society of Western Australia*, 91:163-174.

122 Law, B., Mackowski, C., Shoer, L., amd Tweedie, T. (2000) 'Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales'. *Austral Ecology*, 25:160–178.

123 NSW Threatened Species Scientific Committee (2019) *Swift parrot (*Lathamuse discolor*) endangered species listing*. Available at: https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/nsw-threatened-species-scientific-committee/determinations/final-determinations/2000-2003/swift-parrot-lathamus-discolor-endangered-species-listing.

to recolonise burnt forest (for example koala[124, 125, 126, 127] and greater glider[128, 129, 130, 131, 132]) and this will allow some time for this to occur.

In management zones rated as low risk, no further assessments or measures are required. This reflects the inherent risk managed by the Coastal IFOA in a pre-2019/20 fire season. Historically, FCNSW has managed the risks related to wildfire and forestry operations without this being specified in the Coastal IFOA. Forestry operations in fire-affected mixed forests in NSW have historically been delayed or minimised, with FNCSW shifting operations elsewhere to let burnt forests recover for a period of time. After which, operations resume under standard prescriptions. While not explicitly stated, previously wildfires were an accepted part of operating under the Coastal IFOA and FCNSW has managed operations and the forests as they recover.

5.3 Gateway 2 assessment

Gateway 2 uses the post-fire spectral recovery index to plan the permanent and temporary exclusions required for medium and high risk management zones. This is a desktop assessment that occurs at the operational scale in state forest (i.e. local landscape area). The Gateway 2 assessment provides a test for whether medium or high risk management zones can proceed to Gateway 3. The following subsections outline the desktop test process for medium and high risk areas. If the desktop test results in a 'proceed' outcome, then the local landscape area can proceed to the Gateway 3 assessment.

Medium risk areas have a desktop test to determine if additional temporary exclusions can be met in the local landscape area

This desktop assessment is conducted by FCNSW to determine if the additional retention area in temporary refuges can be accommodated in the local landscape area (**Figure 14**). The additional retention is an area that is equivalent in size to the area of forest in existing exclusions that experienced high or extreme severity fire and has not met the recovery threshold of 80 to 99 percent. This is called a 'temporary refuge' and is in addition to mapped exclusions, wildlife habitat clumps and tree retention clumps (discussed in **Section 5.5**). The priority post-fire habitat for inclusion in temporary refuges is unburnt and lightly burnt forest.

124 Matthews, A., Lunney, D., Gresser, S. and Maitz, W. (2016) 'Movement patterns of koalas in remnant forest after fire'. *Australian Mammalogy*, 38:91-104

125 Matthews, A., Lunney, D., Gresser, S. and Maitz, W. (2007) 'Tree use by koalas *Phascolarctos cinereus* after fire in remnant coastal forest'. *Wildlife Research*, 34:84-93.

126 Lunney, D., Sonawane, I., Wheeler, R., Tasker, E., Ellis, M., Predavec, M. and Fleming, M. (2020) 'An Ecological Reading of the History of the Koala Population of Warrumbungle National Park'. Proceedings of the Linnean Society of New South Wales, 141, Supplement, S131-S154; Lutze, M., Ades, P. and Campbell, R. (2004) 'Review of measures of site occupancy by regeneration'. *Australian Forestry*, 67:164-171.

127 Law, B., Caccamo, G., Wimmer, J., Truskinger, A., McConville, A., Brassil, T., Stanton, M. and Gonsalves, L., (2017) *A predictive habitat model for Koalas Phascolarctos cinereus in north-east New South Wales: Assessment and field validation.* State of New South Wales through Department of Industry

128 Andrew, D., Koffel, D., Harvey, G., Griffiths ,K. and Fleming, M. (2014) 'Rediscovery of the Greater Glider *Petauroides volans* (Marsupialia: Petauroidea) in the Royal National Park, NSW'. Australian *Zoologist* 37:23-28.

129 van der Ree, R., and Loyn, R.H. (2002) 'The influence of time since fire and distance from fire boundary on the distribution and abundance of arboreal marsupials in *Eucalyptus regnans*-dominated forest in the Central Highlands of Victoria'. *Wildlife Research*, 29:151-158.

130 McLean, C. M., Kavanagh, R. P., Penman, T. and Bradstock, R. (2018) 'The threatened status of the hollow dependent arboreal marsupial, the Greater Glider (*Petauroides volans*), can be explained by impacts from wildfire and selective logging'. *Forest Ecology and Management*, 415:19-25.

131 Fleay, D. (1947) *Gliders of the Gum Trees*. Bread and Cheese Club: Melbourne.

132 Fox, A. (1978) 'The '72 fire of Nadgee Nature Reserve'. *Parks and Wildlife*, 2:5-24.

If the area required to meet the additional retention cannot be found, then harvesting is not allowed in the local landscape area. If harvesting were to be permitted, it would impact on the area of functioning habitat that the exclusions would have provided prior to the fires at the local landscape area.

Planning the variable retention requirement uses three steps to determine the additional temporary retentions required:

- **Step 1** – determine mapped exclusions impacted by high and extreme severity fire during the 2019/20 wildfires (based on DPIE-EES' FESM version 3). Any areas of permanent exclusions that are not mapped as being impacted by high or extreme severity fire will continue to contribute to the local landscape area retention requirement. If any errors are identified in the application of FESM at the operational scale, RAFIT can be used in those areas.
- **Step 2** – determine recovery of mapped high and extreme severity areas since the fires (based on DPIE-EES/DPI's post-fire spectral recovery index). Areas of mapped high and extreme severity fires are intersected with areas of spectral recovery that meet or exceed 80 percent and less than 100 percent recovery to the pre-fire value. These areas are considered to have experienced a strong recovery of vegetation, which can include canopy and groundcover recovery, until confirmed by field surveys at Gateway 3. Areas of mapped exclusions that have met or exceeded this 80 percent and less than 100 percent spectral recovery threshold are considered to provide functioning habitat. The areas showing strong vegetation recovery are excluded from the area of mapped high and extreme severity used in this assessment (as illustrated in **Figure 13**).
- **Step 3** – determine temporary retention requirements. Areas that were affected by high or extreme severity fire that have not met or exceeded the 80 percent and less than 100 percent spectral recovery threshold will be supplemented by an equivalent area retained in temporary refuge to maintain the original pre-fire area of functioning habitat. As a result, the temporary refuge area must be set aside and retained in the local landscape area until a future reassessment changes the risk rating of the management zone (see the post-fire exclusion example in **Figure 14**).

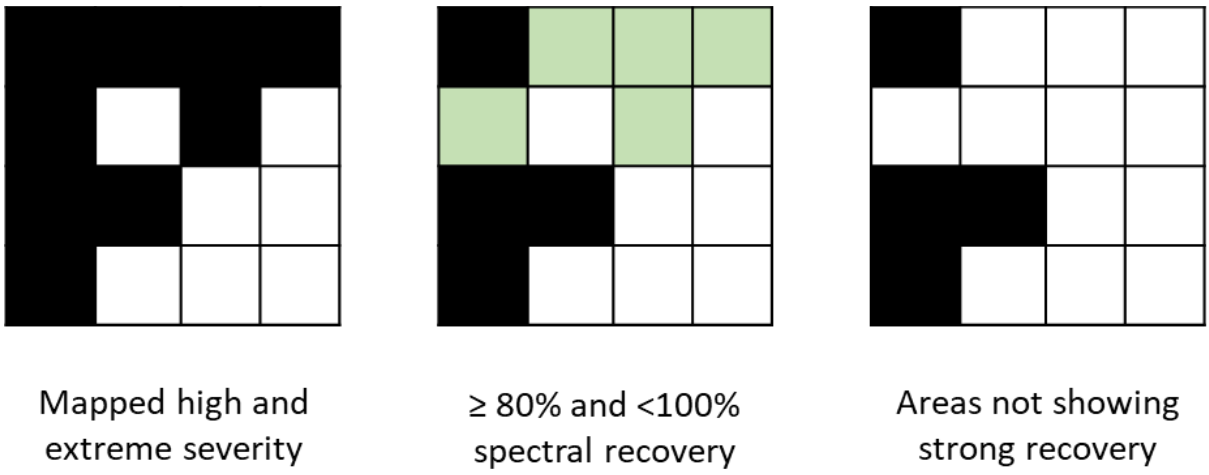

Figure 13: Illustration of how spectral recovery is accounted for in impacted areas over time

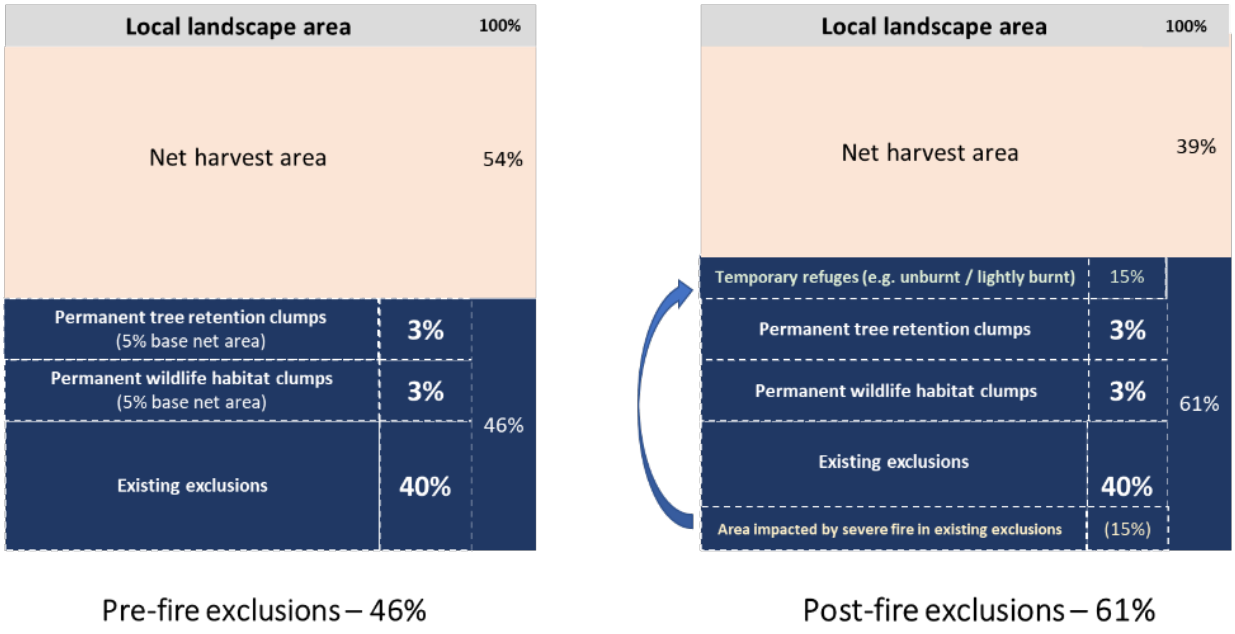

Figure 14: Example calculation of the variable retention required in medium risk local landscape area – these tables illustrate how severely fire-affected exclusions are temporarily supplemented and the impact on net harvest area[133]

High risk areas have a desktop test for fire severity and extent threshold in the local landscape area

This desktop assessment is conducted by FCNSW to evaluate if the burnt area threshold has been exceeded. The test will check if the local landscape area has experienced greater than 10 percent high or extreme severity fire as mapped using FESM version 3, except in forests dominated by obligate seeders, such as alpine ash, where moderate, high and extreme severity classes should be considered in the test. RAFIT mapping can be applied where data gaps exist in FESM.

The intent of this test is to direct harvesting away from unburnt and lightly burnt areas. In an extensively burnt management zone these remaining areas represent critical habitat for forest dependent flora and fauna. Instead, harvesting will be directed towards more severely burnt areas, providing a limited opportunity for harvesting and silvicultural approaches intended to promote future high-quality wood supply.

In some situations, harvesting may not be commercially viable after meeting the retention requirements at the local landscape area due to previous harvesting history in that local landscape area. In other words, after temporarily protecting additional areas in the local landscape area, the remainder may be immature regrowth not ready for commercial harvesting or there may not be enough suitable trees available to make operations commercially viable.

133 Note: the base net area is the area of the local landscape area or compartment minus the exclusions. Wildlife habitat clumps are a proportion of the base net area of the local landscape area, and tree retention clumps area a proportion of the base net area of the compartment.

5.4 Gateway 3 assessment

Gateway 3 consists of field-based assessments at the operational scale in medium or high risk management zones (i.e. local landscape area and compartment or coupe). The Gateway 3 assessment involves two field-testing components.

These on-ground field tests are conducted by FCNSW prior to planning harvesting operations in compartments within local landscape areas in medium and high risk management zones. These field tests will be conducted by FCNSW's trained field staff to confirm remote sensing observations used in the Gateway 2 assessment. The tests are rapid, plot-based assessments involving two on-ground ecological assessments for canopy status and vegetated groundcover recovery:

- **Post-fire spectral recovery index validation assessment** will be conducted in permanent and temporary exclusions to confirm the post-fire status of the retained area. DPIE-EES is currently developing the sampling method to use as part of the Gateway 3 assessments. FCNSW needs to be closely consulted as part of this process to ensure the method is operationally feasible and safe, and improvements to the recovery mapping benefit from on-ground knowledge and interpretation. Sampling design will include multiple plots. Field measures will be simple and objective to relate field measures of canopy cover to satellite-derived products. If the assessment shows that the assessed forest canopy has not recovered to a status at or above the 80 percent threshold as indicated by the remote sensing data, then harvesting is not allowed in the local landscape area. The Commission notes that this field data will also contribute to adaptive updating of the remote sensing algorithms for forest recovery.
- **The groundcover assessment** will be conducted in riparian exclusion zones only, in all compartments within the local landscape area where harvesting is proposed, and will check if vegetated groundcover is at least 70 percent of the benchmark groundcover for the vegetation type.[134] Harvesting is not allowed in the local landscape area if the groundcover recovery threshold has not been met.

If all field tests result in a 'proceed' outcome, then forestry operations can be planned consistent with the risk rating from the Gateway 1 assessment (i.e. Coastal IFOA plus additional measures consistent with medium or high risk ratings, noting different retention requirements).

FCNSW will still be required to conduct broad area habitat searches and targeted species surveys in accordance with standard Coastal IFOA prescriptions. If the most recent broad area habitat survey or targeted flora and fauna surveys were conducted prior to the wildfire, these must be undertaken again ahead of the planned harvesting operation.

134 State of NSW (n.d.) *BioNet Vegetation Classification*. Website available online to registered users at: https://www.environment.nsw.gov.au/NSWVCA20PRapp/LoginPR.aspx?ReturnUrl=%2fNSWVCA20PRapp%2fdefault.aspx.

5.5 Additional measures for medium and high risk areas

In local landscape areas that have been rated as medium or high risk through the Gateway 3 assessment, additional measures are required to be applied in addition to standard Coastal IFOA prescriptions. The Commission has developed additional measures to mitigate the risks of forestry operations in these areas and maintain Coastal IFOA objectives and outcomes. In developing the additional measures, the Commission considered:

- literature on best practice forest management – a summary of key literature used is provided in **Chapter 7**
- advice from the review's expert panel and other experts
- operational and compliance considerations from FCNSW and EPA
- post-fire prescriptions proposed by agencies – a summary of the Commission's analysis of the proposed prescriptions is provided in **Appendix 6**.

Table 16 summarises the additional measures, which are applied at the operational scale (local landscape area).

The impacts of and recovery from fire are not homogenous. Wildfires result in a mosaic of unburnt, lightly burnt, and more severely burnt forest, while recovery is dependent on many biotic and abiotic factors. Retention patches have been found to provide critical refuges for species in harvested coupes.[135, 136, 137] From this, it can be inferred that unburnt and lightly burnt forest patches provide similar functions for flora and fauna recovering after wildfire and assist species to recolonise forest as it recovers.[138] This is supported by the occurrence of fauna in refugia in post-fire landscapes.[139] Unburnt and lightly burnt patches contain ecosystem legacies – the biological remnants left after wildfire – such as feed and habitat trees, intact canopy and understorey, coarse woody debris, and the plants and animals dependent on these features.

The additional measures are designed to identify and protect these ecosystem legacies in temporary refuges. To do this, the measures are designed to provide some flexibility in the planning and application of additional measures across local landscape areas, as each local landscape area will have experienced different fire extent and severity and forests will recover differently depending on the species.

This approach will also provide some flexibility for FCNSW to conduct harvesting operations and apply the most appropriate silvicultural methods to achieve effective forest regeneration

135 Baker, S.C., Halpern, C.B., Wardlaw, T.J., Crawford, R.L., Bigley, R.E., Edgar, G.J., Evans, S.A., Franklin, J.F., Jordan, G.J., Karpievvitch, Y., Spies, T.A. and Thomson, R.J. (2015) 'Short- and long-term benefits for forest biodiversity of retaining unlogged patches in harvested areas.' *Forest Ecology and Management*, 353:187-195.

136 Baker, S.C., Halpern, C.B., Wardlaw, T.J., Kern, C., Edgar, G.J., Thomson, R.J., Bigley, R.E., Franklin, J.F., Gandhi, K.J.K., Gustafsson, L., Johnson, S., Palik, B.J., Spies, T.A., Steel, E.A., Weslien, J. and Strengbom, J. (2016) 'A cross-continental comparison of plant and beetle responses to retention of forest patches during timber harvest.' *Ecological Applications*, 26:2495-2506.

137 Stephens, H.C., Baker, S.C., Potts, B.M., Munks, S.A., Stephens, D. and O'Reilly-Wapstra, J.M. (2012) 'Short-term responses of native rodents to aggregated retention in old growth wet Eucalyptus forests.' Forest *Ecology and Management*, 267:18-27.

138 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

139 Berry, L.E., Driscoll, D.A., Banks, S.C. and Lindenmayer, D.B. (2015) 'The use of topographic fire refuges by the greater glider (*Petauroides volans*) and the mountain brushtail possum (*Trichosurus cunninghami*) following a landscape-scale fire.' *Australian Mammalogy*, 37:39-45.

for both ecological and high-quality future wood supply outcomes. This is important for tree species that are competition intolerant. While recognising there is significant variation, most eucalypts are competition intolerant and require sufficient light along with other favourable site conditions (for example, soil nutrients and water availability), to promote good regeneration outcomes.[140] Appropriate silvicultural approaches will also enable weed incursions to be managed or overstorey regeneration failure to be addressed at a limited scale.

Temporary refuges proposed under the additional measures are in addition to existing exclusions, including wildlife habitat and tree retention clumps, at compartment and local landscape area scales. Existing exclusions are permanently retained, and no harvesting operations can occur in them. The additional measures do not change retention requirements or harvesting restrictions for existing exclusions, which include:

- **mapped exclusions under the Coastal IFOA** – for example, riparian, old growth, and rainforest areas (including conditions 49, 51, 52, 59, 60 and 61 of the Coastal IFOA)
- **wildlife habitat clumps** – these are a minimum of 1 hectare in size and cover at least 5 percent of the base net area of each local landscape area (Condition 50 of the Coastal IFOA)
- **tree retention clumps** – these range in size from 0.1 to 2 hectares, and cover between 5 to 8 percent of the base net area in each compartment (Condition 63 of the Coastal IFOA).

140 Florence, R.G. (2004) *Ecology and silviculture of eucalypt forests*. The Australian National University. CSIRO Publishing.

Table 16: Proposed additional measures where mitigations are required in addition to Coastal IFOA standard prescriptions

Risk rating	Overview of additional measures	Rationale	Coastal IFOA objectives met
High risk	Temporary refuges in priority post-fire habitat are retained to increase retention to at least 75 percent of the local landscape area. Priority post-fire habitat for inclusion in temporary refuges is forest mapped as unburnt, low and moderate severity, except for local landscape areas dominated by obligate seeders such as alpine ash where priority post-fire habitat for temporary refuges is unburnt and low severity fire areas. This should be guided by fire refugia mapping (as mapped by the Commission for this review, see **Box 6**). If additional area is required to meet the 75 percent retention requirement, the following are suggested for consideration: ▪ burnt areas adjacent to existing exclusions or clumps ▪ an additional 20-metre buffer on Class 3 streams ▪ areas of forest that experienced high or extreme severity fire that have met the spectral recovery index threshold (≥80 percent and <100 percent), except for local landscape areas dominated by obligate seeders (such as alpine ash) where areas of moderate, high or extreme severity classes that have met the spectral recovery index threshold could be considered. No more than 25 percent of the local landscape area can be harvested. Mapped exclusions, and wildlife habitat and tree retention clumps are retained in accordance with standard Coastal IFOA conditions and contribute to the 75 percent retention requirement. The minimum size requirement for temporary refuges is 0.5 hectares. There is no maximum size requirement. Note: the intent is to retain priority post-fire habitat where it exists across the local landscape area, especially areas where ecological structure and function are high. In the 25 percent of each local landscape area where harvesting is allowed: ▪ the operations must be conducted in accordance with the distribution, return time, adjacency and other limits specified in conditions under Division 2 of the Coastal IFOA conditions ▪ pre- and post-harvest burns are not allowed ▪ limited mechanical disturbance of groundcover or understorey to manage weed infestations or overstorey regeneration failure is permitted ▪ contrary to Coastal IFOA Protocol 31.4(2), harvesting operations in high risk management zones can be planned and undertaken where the primary purpose is NOT to obtain high quality products, as long as FCNSW can demonstrate that the primary purpose of the operation is to promote future high-quality wood supply and that without intervention this will not occur. This demonstration should provide evidence related to fire regeneration strategies of the tree species ▪ in alpine ash forests, such as in the Bago-Maragle management zone, the Coastal IFOA requirement to retain all dead standing trees in the net harvest area under Condition 64.2(b) does not apply. However, large (>30 centimetre diameter at breast height and >3 metres tall) dead standing trees including with hollows should be retained at a rate between two to five per hectare. If there has been a large mortality event following the fires and there are no living hollow-bearing trees, large dead standing trees with hollows (if available or without if not available) should be retained at a rate of 10 per hectare. If a broad area habitat search or a targeted flora or fauna survey has not been conducted since the wildfire event, these must be conducted prior to the harvesting operation in accordance with requirements in the standard Coastal IFOA prescriptions. For a period of 10 years, two recruitment trees per hollow-bearing tree required to be retained under standard Coastal IFOA prescriptions. Recruitment trees can be located in tree clumps. If eight hollow-bearing trees per hectare are not available retain suitable substitutes (in priority order: potential future hollow-bearing tree, largest mature tree in the stand, regrowth tree that is not suppressed). Hollow-bearing trees and recruitment trees can be retained in clumps or individually across the net harvest area.	Coastal IFOA objectives can be maintained by heavily restricting harvesting and avoiding harvesting in unburnt and lightly burnt forest. The work by Thorn *et al* suggests at least 75 percent of the area disturbed should be retained to limit the cumulative impacts of disturbance and salvage harvesting on biodiversity.[141] This suggests that within a local landscape area no more than 25 percent of the fire-affect forest should be harvested until the impacts of the fires on forest recruitment and functioning have recovered. Coastal IFOA objectives are maintained by implementing silviculture appropriate to the regeneration requirements of and to promote the natural floristic composition of forest flora. Extensive, severe wildfires may compromise the ecological structure and function of forest and the reserve system. Wildfires create a mosaic of unburnt, lightly burnt and more severely burnt forest across the landscape. In more extensively burnt management zones with a high risk rating, unburnt and lightly burnt patches of forest provide critical habitat for the survival and recovery of forest dependent fauna and flora. Harvesting in these areas should be avoided. Harvesting risks can be mitigated by restricting operations to no more than 25 percent of a local landscape area and making unburnt and lightly burnt habitat off-limits to harvesting, i.e. ecosystem legacies are identified and retained in temporary refuges within the local landscape area. Temporary refuges in state forest that protect ecosystem legacies will help species recover and recolonise more severely burnt areas. Hollow recruitment trees and suitable substitute hollow-bearing trees are proposed here as a temporary measure while an existing process under the Coastal IFOA monitoring program considers if the standard prescriptions are effective to maintain hollow-bearing tree resources. References and further detail are provided in **Chapter 7**	*Maintains ecological function and habitat connectivity, and maintains the persistence of native species* by heavily restricting harvesting and avoiding operations in unburnt and lightly burnt forest until forest recovery indicator thresholds are met *Protects water quality and aquatic habitat* by ensuring groundcover recovery thresholds are met in riparian buffers and limiting the extent of harvesting operations across a catchment *Promotes forest regeneration and structure* for ecological outcomes by avoiding or limiting potential cumulative impacts and for wood supply outcomes by providing a restricted opportunity to undertake limited commercial harvesting or to apply silvicultural approaches that will promote futureHQ wood supply

[141] Thorn, S. Chao, A., Georgiev, K.B., Müller, J. Bässler, C., Campbell J.L., Castor, J., Chen, Y.-H., Choi, C.-Y., Cobb, T.P., Donato, D.C., Durska, E., Macdonald, E., Feldhaar, H., Fontaine, J.B., Fornwalt, P.J., Hernández, R.M.H., Hutto, R.L., Koivula, M., Lee, E.-J., Lindenmayer, D., Mikusiński, G., Obrist, M.K., Perlik,M., Rost, J., Waldron, K., Wermelinger, B., Weiß, I., Zmihorski, M., & Leverkus, A.B. (2020) 'Estimating retention benchmarks for salvage logging to protect biodiversity'. *Nature Communications*, 11:4762.

Risk rating	Overview of additional measures	Rationale	Coastal IFOA objectives met
Medium risk	Temporary refuges in priority post-fire habitat are retained across the local landscape area equivalent in size to the area of mapped exclusions affected by high and extreme severity fire that have not met the spectral recovery threshold (≥80% and <100%). Mapped exclusions, and wildlife habitat and tree retention clumps are retained in accordance with standard Coastal IFOA prescriptions. Priority post-fire habitat for temporary refuges is forest mapped as unburnt, low and moderate severity, except for local landscape areas dominated by obligate seeders such as alpine ash where priority post-fire habitat for temporary refuges is unburnt and low severity fire areas. This should be guided by fire refugia mapping (as mapped by the Commission for this review, see **Box 8**). Within temporary refuges, the following are suggested for prioritisation with the retained area: ▪ areas adjacent to existing exclusions or clumps ▪ an additional 20-metre buffer on class 3 streams ▪ unburnt areas then lightly burnt areas showing stronger vegetation recovery. If there is insufficient forest mapped as unburnt, low and moderate severity to meet the temporary refuge retention requirement, forest showing strong recovery can also be retained to meet the requirement (i.e. areas that experienced high or extreme severity fire that have met or exceeded the spectral recovery index threshold (≥80% and <100%), except for local landscape areas dominated by obligate seeders (for example, alpine ash) where areas of moderate, high or extreme severity classes that have met the spectral recovery index threshold could be considered)). The minimum size requirement for temporary refuges is 0.5 hectares. There is no maximum size requirement. Note: the intent is to retain priority post-fire habitat where it exists across the local landscape area, especially areas where ecological structure and function are high. In the proportion of the local landscape area where harvesting is allowed, the operations must be conducted in accordance with the distribution, return time, adjacency and other limits specified in conditions under Division 2 of the Coastal IFOA conditions. In alpine ash forests, such as in the Bago-Maragle management zone, the Coastal IFOA requirement to retain all dead standing trees in the net harvest area under Condition 64.2(b) does not apply. However, large (>30 cm DBH and >3 metres tall) dead standing trees including with hollows should be retained at a rate between 2-5 per hectare. If there has been a large mortality event following the fires and there are no living hollow-bearing trees, large dead standing trees with hollows (if available or without if not available) should be retained at a rate of 10 per hectare. If a broad area habitat search or a targeted flora or fauna survey has not been conducted since the wildfire event, these must be conducted prior to the harvesting operation in accordance with requirements in the standard Coastal IFOA prescriptions. For a minimum period of 10 years, retain 2 recruitment trees per hollow-bearing tree required to be retained under standard Coastal IFOA prescriptions. If 8 hollow-bearing trees per hectare are not available retain suitable substitutes (in priority order: potential future hollow-bearing tree, largest mature tree in the stand, regrowth tree that is not suppressed). Hollow-bearing trees and recruitment trees can be retained in clumps or individually across the net harvest area.	Coastal IFOA retention objectives are maintained by supplementing fire-affected exclusions with unburnt or lightly burnt areas within the net harvest area at the local landscape area scale. In less extensively burnt management zones, risks associated with harvesting can be mitigated by directing operations away from more severely fire-affected forest and temporarily increasing the area where harvesting is not allowed. These additional temporary refuges are located in unburnt and lightly burnt forest with the intent of maintaining an equivalent area of functional habitat in retained areas (i.e. where harvesting is not permitted) as provided by exclusions prior to the 2019/20 wildfires. Hollow recruitment trees and suitable substitute hollow-bearing trees are proposed here as a temporary measure while an existing process under the Coastal IFOA monitoring program considers if the standard prescriptions are effective to maintain hollow-bearing tree resources. References and further detail are provided in **Chapter 7**	*Maintains ecological function and habitat connectivity, and maintains the persistence of native species*, by restricting harvesting where this is a need to temporarily offset state forest exclusions that have been more severely burnt *Protects water quality and aquatic habitat* by ensuring groundcover recovery thresholds are met in riparian buffers and limiting the extent of harvesting operations across catchments that have been more severely burnt *Promotes forest regeneration and structure* for ecological outcomes by avoiding or limiting potential cumulative impacts in more severely burnt areas and for wood supply outcomes by providing some flexibility to plan operations and enable sufficient size canopy openings in forest types that are shade intolerant with the intent to promote regeneration for future high quality wood supply

Box 6 – Method to develop refugia mapping

For this review, the Commission developed a refugia layer, which mapped areas where no severe fire occurred in the fire scar area of the 2019/20 wildfires and also areas that had experienced minimal fire over the last 50 years and minimal harvesting over the last 20 years.

This work used FESM mapping of the 2019/20 wildfires to locate the unburnt and lightly burnt areas (refugia) and then classify each refugium based on how often it had been burnt prior to the 2019/20 wildfires. This used the fire frequency thresholds and mapping product prepared by the University of Wollongong and used in this review (for example, long unburnt, vulnerable, within threshold or too frequently burnt).

The approach merged FESM unburnt, low and moderate severity categories into patches of forest. Refugia patches in the Tumut subregion used FESM unburnt and low severity categories only. Very small refugia patches (less than 1 hectare) were removed. Very small areas (less than 1 hectare) of non-refugia (mapped high and extreme severity) within patches of mapped refugia were merged into the refugia.

By considering both the 2019/20 fire severity mapping and if the area was long unburnt enable deterministic refugia to be located. Deterministic refugia are those that are more persistent in the landscape due to their topographic situation and vegetation characteristics. They include steep southerly slopes, gullies, gorges, tall wet forests, and rainforests.

5.6 Reassessment process

The reassessment process is intended to be undertaken periodically and to be updated and refined using the best available evidence, including new monitoring or remote sensing data.

Management zones that received a medium risk rating at Gateway 1 will be reassessed annually to provide an updated risk rating for the management zone. The next reassessment for medium risk areas would be March 2022, once new spectral recovery data is available.

Management zones that received a high or extreme risk rating at Gateway 1 will not be reassessed for three years following the wildfires (i.e. three years from February 2020), after which they will be reassessed every 12 months.

At Gateway 2 or Gateway 3, local landscape areas that were assessed as extreme risk can be reassessed annually considering the recovery status of the mapped high or extreme severity areas (noting this will include mapped moderate severity areas in forest such as alpine ash).

Three-year recovery period before reassessment in high and extreme risk management zones

Ecosystem recovery that resembles the function of a pre-fire state, or similar condition, can take significant time. A three-year recovery period is recommended before extreme and high risk management zones can be reassessed. No, or very restricted harvesting can occur in this three-year period. This precautionary measure allows a longer time for ecological recovery of some functions – such as mid-storey reestablishment and canopy flowering – in areas most impacted by severe wildfire.

In comparison, medium risk management zones can be reassessed annually.

The evidence considered in recommending a three-year recovery period before reassessment includes:

- various studies considered the time to flower or fruit post-fire, which is important for species dependent on these for food resource, for example:
    - in the north coast region, a study found that 12 species of eucalypts that experienced crown scorch due to wildfire or a hot planned fire had flowering delayed by up to three years[142]
    - in the Sydney region (noting this is outside the Coastal IFOA) a study found that *E. luehmanniana*, a wet-mallee eucalypt restricted to the Sydney region, took two to four years to flower and five to six years to produce fruit post-fire[143]
    - a Western Australian study also found that resprouting tree species (which included Eucalyptus spp.) took 36.9 months on average to flower post-fire, while obligate seeding tree species took 49.5 months on average[144]
    - the same Western Australian study found that approximately 30 percent of understorey species in southwest Western Australia flowered within one year post-fire, 97 percent within three years and 100 percent of all plants within five years[145]
- understorey plant community richness and composition are influenced by environmental factors other than management with plant community composition and richness reflecting the outcomes of the last wildfire and plant community dynamics (i.e. ecological succession)[146, 147, 148]
- mechanical harvesting following wildfire can impact fire-cued regeneration, which can lead to negative impacts on plant richness and composition[149, 150] however, ensuring 75 percent or more of the disturbed area is retained in post-fire harvesting[151] is critical for

142 Law, B., Mackowski, C., Shoer, L. and Tweedie, T. (2000) 'Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales'. *Austral Ecology*, 25:160–178.

143 Davies, S.J. and Myerscough, P.J. (1991) 'Postfire Demography of the Wet-Mallee *Eucalyptus luehmanniana* F Muell (Myrtaceae)'. *Australian Journal of Botany*, 39:459 - 466.

144 Burrows, N.D., Wardell-Johnson, G. and Ward, B. (2008) 'Post-fire juvenile period of plants in south-west Australia forests and implications for fire management'. *Journal of the Royal Society of Western Australia*, 91:163-174.

145 *Ibid.*

146 Penman, T.D., Binns, D.L., Shiels, R.J., Allen, R.M. and Kavanagh, R.P. (2008) 'Changes in understorey plant species richness following logging and prescribed burning in shrubby dry sclerophyll forests of south-eastern Australia'. *Austral Ecology*, 33:197–210.

147 Penman, T.D., Binns and Kavanagh ,R.P. (2008) 'Quantifying successional changes in response to forest disturbances'. *Applied Vegetation Science*, 11:261-268.

148 Penman, T.D., Binns, D.L., Shiels, R.J., Allen, R.M. and Penman, S.H. (2011) 'Hidden effects of forest management practices: responses of a soil stored seed bank to logging and repeated prescribed fire'. *Austral Ecology*, 36,:571-580.

149 Leverkus, A.B., Lorite, J., Navarro, F.B., Sanchez-Canete, E.P. and Castro, J. (2014) 'Post-fire salvage logging alters species composition and reduces cover, richness, and diversity in Mediterranean plant communities'. *Journal of Environmental Management*, 133:323e331.

150 Blair, D.P., McBurney, L.M., Blanchard, W., Banks, S.C. and Lindenmayer, D.B. (2016) 'Disturbance gradient shows logging affects plant functional groups more than fire'. *Ecological Applications*, 26:2280-2301.

151 Thorn, S. Chao, A., Georgiev ,K.B., Müller, J. Bässler, C., Campbell J.L., Castor, J., Chen, Y.-H., Choi, C.-Y., Cobb, T.P., Donato, D.C., Durska, E., Macdonald, E., Feldhaar, H., Fontaine, J.B., Fornwalt, P.J., Hernández, R.M.H., Hutto, R.L., Koivula, M., Lee, E.-J., Lindenmayer, D., Mikusiński, G., Obrist, M.K., Perlik,M., Rost, J., Waldron, K., Wermelinger, B., Weiß, I., Zmihorski, M. and Leverkus, A.B. (2020) 'Estimating retention benchmarks for salvage logging to protect biodiversity'. *Nature Communications*, 11:4762.

reducing the impacts of mechanical disturbance on the 2019/20 fire-cued regeneration cohort, irrespective of plant traits[152]

- limited studies suggest that nectar and fruit resources will take longer to recover than browsing resources, and for fauna reliant on tree-based nectar resources, this recovery could take two to four years[153]
- within post-fire landscapes, heterogeneity in fire severity typically creates a mosaic of habitat at broad spatial scales and this heterogeneity is important for the persistence and recovery of fauna[154]
- koalas are able to use regenerating forests within months post-fire for forage and due to their mobility are able to recolonise burnt areas quickly[155, 156] however when wildfire impacted most of the Warrumbungle National Park at high to extreme severity the koala population had not recolonised the fire-affected area six years later[157]
- post the 2019/20 wildfires, koalas were also recorded in areas that experienced high severity fire, but not in the few sampled areas where high severity fires were also widespread[158]
- greater gliders have been observed in fire-affected forests within months,[159, 160] however recolonisation is more often reported to take several years (for example, 3-4 years,[161, 162] 8-10 years,[163] 11 years[164] and up to 18 years[165])

Further discussion on cumulative impacts including recovery of species following disturbance is provided in **Chapter 7**.

152 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided the Commission for this review.

153 *Ibid*.

154 *Ibid*.

155 Matthews, A., Lunney, D., Gresser, S. and Maitz, W. (2007) 'Tree use by koalas *Phascolarctos cinereus* after fire in remnant coastal forest'. *Wildlife Research*, 34:84-93.

156 Matthews, A., Lunney, D., Gresser, S. and Maitz, W. (2016) 'Movement patterns of koalas in remnant forest after fire'. *Australian Mammalogy*, 38:91-104.

157 Lunney, D., Sonawane, I., Wheeler, R., Tasker, E., Ellis, M., Predavec, M. and Fleming, M. (2020) 'An Ecological Reading of the History of the Koala Population of Warrumbungle National Park'. *Proceedings of the Linnean Society of New South Wales*, 141, Supplement, S131-S154.

158 DPI (2021) *Koala research in NSW forests*. Available at: https://www.dpi.nsw.gov.au/forestry/science/koala-research.

159 Fox, A. (1978) 'The '72 fire of Nadgee Nature Reserve'. *Parks and Wildlife*, 2:5-24.

160 DPIE (2021) *NSW Wildlife and Conservation Bushfire Recovery - Medium-term response plan*. Available at: environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/nsw-wildlife-and-conservation-bushfire-recovery-medium-term-response-plan-200478.pdf.

161 Fleay, D. (1947) *Gliders of the Gum Trees*. Bread and Cheese Club: Melbourne

162 Fox, A. (1978) 'The '72 fire of Nadgee Nature Reserve'. *Parks and Wildlife*, 2:5-24.

163 McLean, C. M., Kavanagh, R. P., Penman, T. and Bradstock, R. (2018) 'The threatened status of the hollow dependent arboreal marsupial, the Greater Glider (*Petauroides volans*), can be explained by impacts from wildfire and selective logging'. *Forest Ecology and Management*, 415:19-25.

164 van der Ree, R. and Loyn, R.H. (2002) 'The influence of time since fire and distance from fire boundary on the distribution and abundance of arboreal marsupials in *Eucalyptus regnans*-dominated forest in the Central Highlands of Victoria'. *Wildlife Research*, 29:151-158.

165 Andrew, D., Koffel, D., Harvey, G., Griffiths ,K. and Fleming, M. (2014) 'Rediscovery of the Greater Glider *Petauroides volans* (Marsupialia: Petauroidea) in the Royal National Park, NSW'. *Australian Zoologist* 37:23-28.

Reassessment datasets and method

The reassessment will continue to use the same datasets:

- **FESM version 3** to identify the baseline of areas affected by high and extreme severity fire during the 2019/20 wildfires (with RAFIT used at Gateway 2 if there are gaps or errors in FESM)
- **Post-fire spectral recovery index** – a recovery index being jointly developed by researchers at DPIE-EES and DPI Forest Science – this uses the normalised burn ratio, which shows the spectral recovery to the pre-fire status.

These datasets, or if available, improved and updated versions, will be used in the reassessment. Additionally, if new data, models or information becomes available on forest or forest dependent species recovery, this can also be used in the reassessment process following consideration of the suitability of the data. This approach will ensure that the best available evidence is used for the assessment. For example, reassessment could be informed by other remote sensing products, such as hyper-spectral imaging.[166]

These datasets should remain in place for future assessments until further work integrating FESM version 3 and spectral recovery observations is undertaken (as described in **Section 4.3**). Future versions of the spectral recovery index may integrate mapped severity to understand where the observed spectral recovery response is occurring. For example, where low severity fire has occurred the fire should not have impacted the canopy, and this means that the observed spectral recovery will be occurring below canopy.

In addition to updated risk assessment results, the reassessment process will also consider data from the DPI Forest Science predicted recovery model. While not informing the risk assessment outcomes, this model indicates the potential recovery timeframe of different areas and is important context to give decision makers an idea of the medium-term trajectory of forest recovery.

The post-fire spectral recovery index will be updated in January each year based on new satellite imagery. In addition, the updated recovery index will be provided to FCNSW so it can consider the exclusions required in local landscape areas in medium or high risk management zones.

Upon receipt of the updated recovery index, the Commission will rerun the management zone risk assessment at Gateway 1 using the reassessment process and datasets described in this section. This assessment will likely be finalised in March each year, with results shared with FCNSW and EPA.

For medium risk management zones, and for high and extreme risk management zones that have completed the three-year recovery period, the reassessment process can be undertaken annually or more frequently if available data allows it. If FCNSW or the EPA consider the Gateway 1 results are not reflective of a management zone due to localised variations, such as the post-fire spectral recovery index being inaccurate or there is a further wildfire, then an exceptional reassessment may be triggered. This assessment should be undertaken in an efficient and transparent manner.

166 Pascucci, S., Pignatti, S., Casa, R., Darvishzadeh, R. and Huang, W. (2020) 'Special issue "hyperspectral remove sensing of agriculture and vegetation" – editorial'. *Remote sensing*, 12:3665.

In addition, the annual health check for the Coastal IFOA monitoring program is due to occur in March/April of each year to discuss the findings of the monitoring program and to suggest any amendments to conditions or protocols of the Coastal IFOA or amendments to the monitoring program itself. During the annual health check, the risk assessment thresholds will be reviewed concurrently with the Gateway 1 reassessment and, if required, the Gateway 1 thresholds may be refined based on additional evidence generated through the monitoring program, specifically the monitoring of harvesting in fire-affected sites. The plan for monitoring harvesting in fire-affected sites can be found on the Commission's website.[167]

[167] Natural Resources Commission (2021) *Monitoring Plan - Harvesting in fire-affected sites*. Available at: https://www.nrc.nsw.gov.au/ifoa-mer.

Part 3 – Wildfire and forestry impacts

6 Implications for achieving Coastal IFOA objectives and outcomes

Forest disturbance by wildfire is a natural process that shapes forest dynamics across the world. However, the scale, severity and duration of the 2019/20 wildfires, and their impact on ecological systems, was unprecedented compared to other fire seasons recorded since European settlement.[168] This changes the risk profile for achieving the objectives and outcomes under the Coastal IFOA.

Understanding the impacts to environmental values from the wildfires is critical to understanding how the risks associated with forestry operations in coastal native state forests have changed.

In order to understand implications for achieving Coastal IFOA objectives and outcomes, the Commission has considered the impacts of the wildfires on environmental values and engaged experts from the NSW Bushfire Risk Management Research Hub at the University of Wollongong to consider past, present and future risks from changing fire regimes.

This chapter presents findings related to:

- environmental impacts of the 2019/20 wildfires to date (**Section 6.1**)
- early evidence of recovery (**Section 6.2**)
- changes and associated risk to fire regimes (**Section 6.3**)
- the implications of future climate scenarios and increasing risks from large-extent fires (**Section 6.4**)
- future risks to Coastal IFOA objectives and outcomes (**Section 6.5**)

6.1 The wildfires had significant environmental impacts

Across Australia, almost 12.6 million hectares burnt from August 2019 to March 2020,[169] including over 20 percent of the total area of Australia's forest biome.[170] Record hot, dry conditions supported 134 'mega-fires' (each over 10,000 hectares) that collectively burnt over 60 percent of the total fire-scar area,[171] including the 0.5 million-hectare Gospers Mountain fire in the Sydney Basin, the largest single wildfire in recorded history.[172] World Heritage listed Gondwana rainforests were also impacted.[173]

168 NSW Government (2020) *Final Report of the NSW Bushfire Inquiry July 2020.* Available at: https://www.nsw.gov.au/nsw-government/projects-and-initiatives/nsw-bushfire-inquiry.

169 Wintle, B.A., Legge, S. and Woinarski, J.C.Z. (2020) 'After the Megafires: What Next for Australian Wildlife?' *Trends in Ecology and Evolution.* 35: 753-757.

170 Boer, M.M., de Rois, V.C. and Bradstock, R.A. (2020) 'Unprecedented burn area of Australian mega forest fires'. *Nature Climate Change.* 10: 171-172.

171 Baranowski, K., Faust, C., Eby, P. and Bharti, N. (2020) 'Quantifying the impact of severe bushfires on biodiversity to inform conservation'. *Research Square.* DOI: 10.21203/rs.3.rs-36234/v1.

172 Boer, M.M., de Rois, V.C. and Bradstock, R.A. (2020) 'Unprecedented burn area of Australian mega forest fires'. *Nature Climate Change.* 10: 171-172.

173 Nolan, R.H., Boer, M.M., Collins, L. Resco de Dios, V., Clarke, H., Jenkins, M., Kenny, B. and Bradstock, R.A. (2020) 'Causes and consequences of eastern Australia's 2019-20 season of mega-fires'. *Global Change Biology.* 26: 1039-1041.

For this review, a comprehensive literature review was undertaken that considered the findings of publicly available scientific literature on the impacts of the 2019/20 wildfires.[174] The reviewers considered that, based on published statistics on flora and fauna impacts, the 2019/20 wildfires are unlikely to represent an immediate existential threat to the persistence of most biodiversity.[175]

However, some species and populations had more than 80 percent of their habitat impacted by the 2019/20 wildfires, which may put them at high risk of habitat and population loss.[176] This included the endangered Bago population of yellow-bellied glider (*Petaurus australis*), the Eurobodalla population of greater glider (*Petauroides volans*), the critically endangered long-nosed potoroo (*Potorous tridactylus*), endangered Hastings River mouse (*Pseudomys oralis*), and, the endangered Pugh's mountain frog (*Philoria pughi*).[177] The reviewers note that the broad scope of these habitat analyses assume homogeneity in fire severity, which is unlikely to have occurred, and this may then overestimate the magnitude of impacts.[178] The role of heterogeneity of fire severity and ecosystem legacies within fire-affected landscapes should be considered in assessing the impacts on habitat.[179]

The review found that, while there have been some post-fire studies and desktop analyses on the impacts of the 2019/20 wildfires in NSW for some key areas (such as flora and fauna distributions and habitat), no post-fire studies were found for others, such as forest regeneration, soil chemistry and forest carbon. Only limited studies on erosion and water quality were found. In addition, limited post-fire species monitoring data has been published.[180]

Early desktop assessments of environmental impacts in the immediate aftermath of the 2019/20 wildfires were prepared by agencies to quantify the potential impacts on wildlife, plants and

174 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided the Commission for this review.
175 *Ibid.*
176 *Ibid.*
177 *Ibid.*
178 *Ibid.*
179 *Ibid.*
180 *Ibid.*

ecological communities and to identify appropriate response and recovery actions.[181, 182, 183, 184,185]

These assessments used a variety of fire mapping products, such as:

- the NSW Rural Fire Service's fire ground map, which provides the outer perimeter of the fire extent and contains both burnt and unburnt areas
- the rapid, national fire severity mapping (GEEBAM)
- DPIE's fire extent and severity mapping (FESM Version 2 or earlier)
- FCNSW's RAFIT mapping tool, which produces an imagery-based classification of the severity of fire impact on forested landscapes.

While these assessments provided useful early data to aid response and recovery actions, NSW Government agencies have adopted FESM version 3, which was released by DPIE in December 2020. FESM version 3 is considered to be an improved and more accurate fire severity mapping product than earlier versions of FESM, [186] GEEBAM or the fire ground map.

The Commission has rerun and conducted targeted analyses using FESM version 3 for the purpose of this review. The following sections provide a summary of these analyses, which have informed the risk-based approach discussed in **Chapter 5**. Also discussed are recently published or available monitoring from agencies on species post-fire persistence.

181 DPIE (2020) *Wildlife and Conservation Bushfire Recovery Immediate Response January 2020*. Available at: https://www.environment.nsw.gov.au/research-and-publications/publications-search/wildlife-and-conservation-bushfire-recovery-immediate-response.

182 DPIE (2020) *NSW Fire and the Environment 2019–20 Summary Biodiversity and landscape data and analyses to understand the effects of the fire events, March 2020*. Available at: https://www.environment.nsw.gov.au/research-and-publications/publications-search/fire-and-the-environment-2019-20-summary.

183 Gallagher, R.V. (2020) *National prioritisation of Australian plants affected by the 2019-2020 wildfire season*. Report to the Commonwealth Department of Agriculture, Water and Environment. Available at: https://www.environment.gov.au/system/files/pages/289205b6-83c5-480c-9a7d-3fdf3cde2f68/files/final-national-prioritisation-australian-plants-affected-2019-2020-bushfire-season.pdf.

184 FCNSW (2020) *2019–20 Wildfires Environmental impacts and implications for timber harvesting in NSW State forests - An assessment of the impact of the 2019-20 fire season on biodiversity, soil and water values and implications for managing ongoing timber harvesting operations in native State forests.* Available at: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/forestry/review-201920-wildfires-environmental-impacts-and-implications-for-timber-harvesting-in-nsw-state-fo.pdf?la=en&hash=9C110E65D0110D0EA93D1DA3A3B186C4D8E2FD9F.

185 FCNSW (2020) *2019–20 Wildfires NSW Coastal Hardwood Forests Sustainable Yield Review*. Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1299388/fcnsw-sustainable-yield-report-2019-20-wildfires.pdf.

186 DPIE (2020) *DPIE Fire Extent and Severity Mapping FESMv3 Factsheet (December 2020)*. Available at: https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm/resource/1ee94f00-6681-410f-af89-14d5bd208eca.

Desktop analysis of fauna species habitat impacts

The impact of the wildfires on ongoing habitat suitability is unknown for most impacted fauna species and requires more time and research.[187] In addition, the lack of knowledge on the impact of fire on biodiversity was reported to have hindered management responses.[188]

Under the Coastal IFOA monitoring program, the Commission has engaged researchers to evaluate the risks to the Coastal IFOA objectives and outcomes as a result of the 2019/20 wildfires and future changes to fire regimes.[189] This includes a desktop review to determine levels of exposure of species habitat to combinations of high and extreme fire severity, timber harvesting, and high wildfire frequency.

Analyses of effects of disturbance regimes on predicted suitable habitat[190, 191] have been carried out for a range of threatened fauna species where habitat suitability mapping is available (**Appendix 7**). This includes 11 mammal, seven bird, five bat, and two amphibian species.[192]

Figure 15 and **Figure 16** show examples of the fauna species habitat mapping used for this analysis[193] overlain with fire severity and extent mapping. **Figure 15** provides the maps for the yellow-bellied glider and spotted-tailed quoll (*Dasyurus maculatus*), showing that around 20 percent of the predicted suitable habitat that occurs in the Coastal IFOA region for both of these species was affected by high to extreme severity fire. **Figure 16** provides the maps for the koala and the rufous scrub bird (*Atrichornis rufescens*), showing that 17 and 19 percent respectively of the suitable habitat that occurs in the Coastal IFOA region for these species was affected by high to extreme severity fire.

187 Ward, M., Tulloch, A.I.T., Radford, J.Q., Williams, B.A., Reside, A.E., MacDonald, S.L., Mayfield, H.J., Maron, M., Possingham, H.P., Vine, S.J., O'Connor, J.L., Massingham, E.J., Greenvile, A.C., Woinarski, J.C.Z., Garnett, S.T., Lintermans, M., Scheele, B.C., Carwardine, J., Nimmo, D.G., Lindenmayer, D.B., Kooyan, R.M., Simmonds, J.S., Sonter, L.J. and Watson, J.E.M. (2021) 'Impact of 2019–2020 mega-fires on Australian fauna habitat'. *Nature Ecology & Evolution*, 4: 1321–1326.

188 Rowley, J.L. Callaghan, C.T. Cornwell, W.K. (2020) 'Widespread short-term persistence of frog species after the 2019–2020 wildfires in eastern Australia revealed by citizen science'. *Conservation Science and Practice*, 2: e287.

189 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

190 Saving our Species Program and Macquarie University (n.d.) *Climate Refugia NSW*. Available at: https://nswclimaterefugia.net//.

191 The University of Wollongong modified koala habitat mapping available on SEED (https://datasets.seed.nsw.gov.au/anzlic_dataset/koala-habitat-information-base-habitat-suitability-models-v1-0) by applying expert knowledge on habitat suitability thresholds to derive the 'habitat suitability above threshold' layer shown in this map. Further information on the method applied is in Bradstock *et al.* (2021).

192 Selection of species was based on availability of predicted suitable habitat information (excluding koala) compiled by DPIE (https://climatechange.environment.nsw.gov.au/Adapting-to-climate-change/Adaptation-Research-Hub/Biodiversity-Node). The analysis intersected predicted species habitat with the boundaries of the Coastal IFOA and the forested portion within it. The area within the forested Coastal IFOA exposed to disturbances (wildfire, harvesting) prior to the 2019/20 fire season was then determined.

193 The predicted suitable habitat mapping used for all species except the koala is from Saving our Species Program and Macquarie University (n.d.) *Climate Refugia NSW*. Available at: https://nswclimaterefugia.net//. Habitat suitability mapping used for the koala was sourced based on the modelling of Law B, Caccamo G, Roe P, *et al.* (2017) 'Development and field validation of a regional, management-scale habitat model: A koala *Phascolarctos cinereus* case study.' *Ecology and Evolution*; 00:1–15 as available on the NSW Government SEED website at: https://datasets.seed.nsw.gov.au/anzlic_dataset/koala-habitat-information-base-habitat-suitability-models-v1-0.

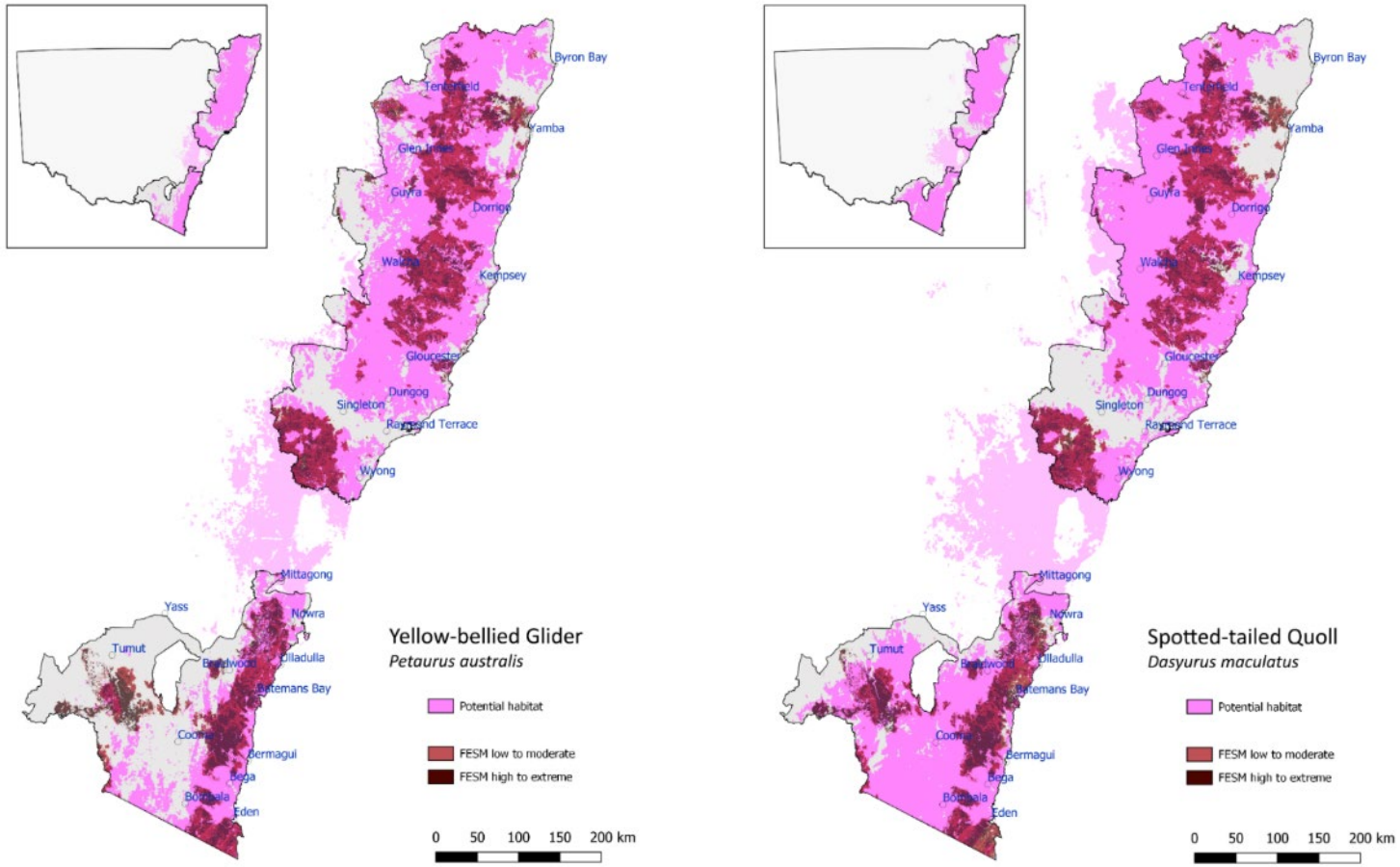

Figure 15: Predicted suitable habitat for yellow-bellied glider (left) and spotted-tailed quoll (right) impacted by the 2019/20 wildfires[194]

194 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

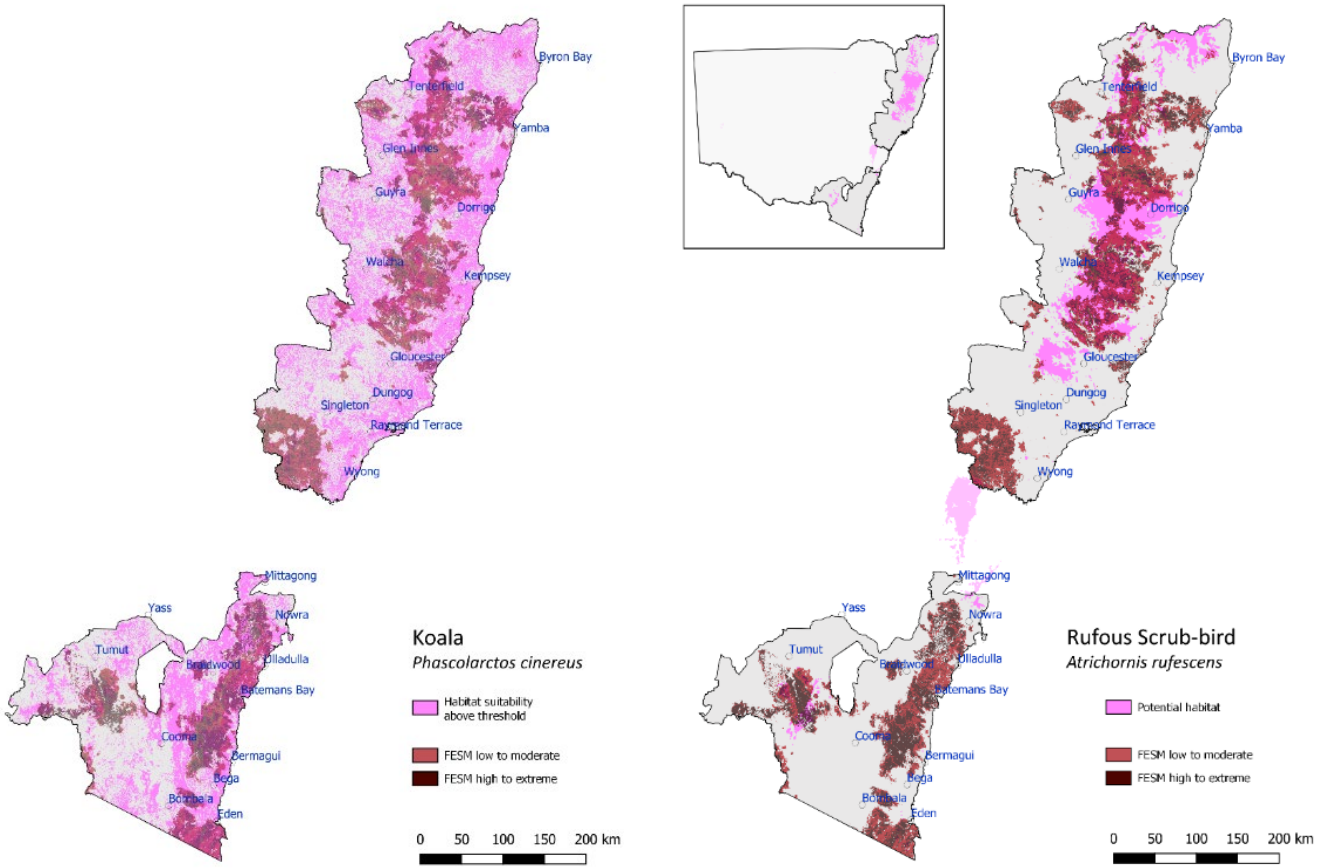

Figure 16: Predicted suitable habitat for koala[195] (left) and rufous scrub bird (right) impacted by the 2019/20 wildfires[196]

195 The University of Wollongong modified koala habitat mapping available on SEED (https://datasets.seed.nsw.gov.au/anzlic_dataset/koala-habitat-information-base-habitat-suitability-models-v1-0) by applying expert knowledge on habitat suitability thresholds to derive the 'habitat suitability above threshold' layer shown in this map. Further information on the method applied is in Bradstock et al (2021).

196 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

The analysis found that significant areas of predicted suitable habitat for the assessed species was impacted by fire in 2019/20, with between 27 and 62 percent affected by fire. In addition, between 13 and 32 percent of this predicted suitable habitat was exposed to high and extreme severity fire (area data is provided in **Appendix 8**). Further:[197]

- Before the 2019/20 wildfires, long-term patterns of high frequency wildfire (greater than four wildfires in the 50-year period before 2019/20) affected a relatively small proportion (between 2 to 9 percent) of the predicted suitable habitat in the Coastal IFOA for the assessed species. The 2019/20 wildfires resulted in a doubling of the proportion of suitable habitat that sits in high disturbance frequencies, ranging from 9 to 15 percent across the assessed species' habitat.
- In the species habitats exposed to high frequency wildfire, just under half was burnt at high or extreme severity in 2019/20.

While the overall impact on species habitat was high, the proportion of predicted habitat for the assessed species that was impacted by high and extreme severity fire, as well as being harvested was relatively low:

- Timber harvesting between 2000 and 2019 affected between 1 and 9 percent of the area of predicted suitable habitat within the Coastal IFOA for the assessed species.
- The combination of past harvesting, high frequency wildfire (i.e. greater than four wildfires in the 50-year period prior to 2019/20) plus high or extreme severity fire during 2019/20 affected 1 percent or less of the area of predicted suitable habitat for the assessed species.

As such, the compounding effects of high frequency wildfire, high to extreme fire severity, and previous harvesting operations were minor in terms of area of predicted habitat affected. However, considering impacts more broadly across the species habitat, the magnitude of the 2019/20 wildfires makes it likely that significant impacts have occurred. Key areas of concern may include areas burnt by high or extreme severity in 2019/20 that had been harvested since 2000 and are exposed to high frequency wildfires.

To address these risks the Commission has adopted a precautionary approach at a management zone level with a multiple gateway assessment approach to consider the risks that harvesting in the fire-affected landscape may have. Further, this includes the temporary suspension of harvesting in management zones where extreme risks have been identified, or additional mitigation measures in management zones where medium or high risks have been identified. This is supported by on-ground checks to consider forest recovery. Importantly, the approach recommended by the Commission includes annual reassessment of recovery and an adaptive management approach to ensure new findings and information can be incorporated into the decision-making framework.

197 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

Desktop analysis of flora impacts

In addition to analysing impacts on fauna habitat (discussed in the previous subsection), the research commissioned through the Coastal IFOA monitoring program[198] has also analysed the change in the fire frequency status of forested vegetation formations in the Coastal IFOA region.[199] High frequency fire that results in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition is listed as a key threatening process in the *Biodiversity Conservation Act 2016*.

To consider fire frequency status, minimum and maximum fire interval thresholds for the major vegetation formations in the Coastal IFOA region were derived[200] and applied (**Table 17**).

Fire interval thresholds provide an indication of the minimum time that the vegetation should remain unburnt following a fire to allow successful reestablishment or the maximum time they should remain unburnt to avoid the stored seed becoming unviable. These thresholds are useful to predict vegetation responses to fire at a coarse level. However, the thresholds are based on the fire response of a set of key species, assuming the fire response of all flora and fauna species in a vegetation formation are reflective of these. In addition, the variability in responses of key species remains largely unknown. This means that fire interval thresholds are not suitable for rigorous application for management purposes. Rather the approach is intended to function as a prompt for decision making and further investigation.

For this analysis, fire interval thresholds based on the NSW Flora Fire Response Database were adopted,[201] which were modified considering relevant and available data, including:

- observed responses of plant traits in the database (for example, resprouting, seedbank type, dispersal)
- observed juvenile periods and observed or estimated life spans of sensitive obligate seeders
- comparison of these data to identify the longest and shortest estimates of these respective attributes in each vegetation formation.

198 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

199 The analysis used DPIE-EES' state-wide vegetation type mapping (February 2021) and 'thresholds of potential concern' used in NSW. These can be used to interpret the potential effects of fire frequency on the status of plant biodiversity. This uses observations of the fire response of plant species, their life history traits and ability to tolerate variations in fire frequency, with state-wide vegetation type mapping.

200 Kenny, B., Sutherland, E., Tasker, E. and Bradstock, R. (2004) *Guidelines for ecologically sustainable fire management*. A report prepared for the NSW Biodiversity Strategy and the NSW National Parks and Wildlife Service.

201 The NSW Bushfire Risk Management Research Hub is currently updating the NSW Flora Fire Response Database (Work Package 4: Fire regime thresholds of potential concern for threatened biodiversity). Further information is available at: https://www.uow.edu.au/science-medicine-health/research/cermb/nsw-bushfire-risk-management-research-hub/.

The fire frequency status of the vegetation formations across the Coastal IFOA were mapped into four categories of plant biodiversity responses to fire frequency:

- **Long unburnt** vegetation has not been burnt in a long time, past the maximum threshold
- **Within threshold** vegetation has current fire intervals that sit within the domain of recommended minimum and maximum intervals between fire and is in a state where an additional fire will not leave it too frequently burnt.
- **Vulnerable** vegetation has been frequently burnt, and due to recent burning may become too frequently burnt if a fire occurs again soon putting plant biodiversity at risk of decline
- **Too frequently burnt** vegetation has been burnt at intervals less than the minimum threshold.

Table 17: Broad fire interval thresholds for relevant major vegetation formations in the Coastal IFOA region[202]

Formation	Minimum threshold (years)	Maximum threshold (years)
Dry Sclerophyll Forests (Shrub/grass sub-formation)	8	50
Dry Sclerophyll Forests (Shrubby sub-formation)	10	30
Forested Wetlands	10	35
Grassy Woodlands	8	50
Rainforests[203]	Not applicable	Not applicable
Wet Sclerophyll Forests (Grassy sub-formation)	15	60
Wet Sclerophyll Forests (Shrubby sub-formation)	20	60

This analysis provides an indication of the potential effects of fire frequency on the status of plant biodiversity. Vegetation formations in the 'vulnerable' and 'too frequently burnt' categories are considered at risk because some plant species do not have sufficient time to complete their normal life cycle (including seeding) and may be lost in a subsequent disturbance. Conversely, formations in the 'long unburnt' category may not have had enough fire to promote healthy regeneration.

The analysis estimates a consistent and large shift in fire frequency status across the most extensive vegetation formations (**Figure 17** and **Figure 18**). Overall, the 2019/20 fire season has

202 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

203 The wildfire resilience and post-fire recovery in fire affected rainforests is poorly understood. This report used the NSW Flora Fire Response Database, which does not have thresholds for rainforest. For rainforest formations, moderate to extreme fire severity classes were considered in the analysis. For all other vegetation formations, high and extreme severity classes were used.

resulted in fire frequency patterns that put more than half of the forested vegetation in the Coastal IFOA at risk of a potential decline in plant diversity. Findings include:

- there were substantial increases in the proportion of area in the 'vulnerable' category, from 19 percent pre-fires to 39 percent post-fires.
- nearly double the area of dry and wet sclerophyll forest formations are now in the 'vulnerable' category when averaged across land tenure categories, and the corresponding shift was even greater in forested wetlands
- the bulk of dry sclerophyll and wet sclerophyll forests and forested wetlands are now estimated to be 'vulnerable' in national parks and state forests
- substantial increases in the proportion of area in the 'vulnerable' category also occurred in grassy woodlands mainly on national parks and state forests
- most of the area of the rainforest formation within the forested portion of the Coastal IFOA was shifted into the 'too frequently burnt' category, although this is based on an assumption that rainforest species have no resilience to fire of which there is limited supporting evidence.[204]

The magnitude of the shifts in the status of vegetation into the 'vulnerable' category greatly elevates the risk that the Coastal IFOA objectives and outcomes related to the risk categories 'maintain ecological function and habitat connectivity' and 'maintain persistence of native species' may be compromised. Given the nature of the thresholds, such an increase in risk will remain elevated over much the Coastal IFOA region for the next five to ten years.[205] The implications for achieving Coastal IFOA objectives and outcomes as a result of this shift in fire frequency patterns is discussed in **Section 6.3**.

Along with adopting a precautionary risk assessment approach, this analysis has been considered in the Commission's recommended pathways via the recovery analysis and on-ground validation of remote sensed spectral recovery.

204 Baker, P.J., Simkin, R., Pappas, N., McLeod, A and, McKenzie, M. (2012) Fire on the mountain: A multi-scale, multi-proxy assessment of the resilience of cool temperate rainforest to fire in Victoria's Central Highlands. In Haberle SG, Bruno D (eds.) *Peopled landscapes: Archaelogical and biogeographic approaches to landscapes*. ANU Press. pp 375-391.

205 *Ibid.*

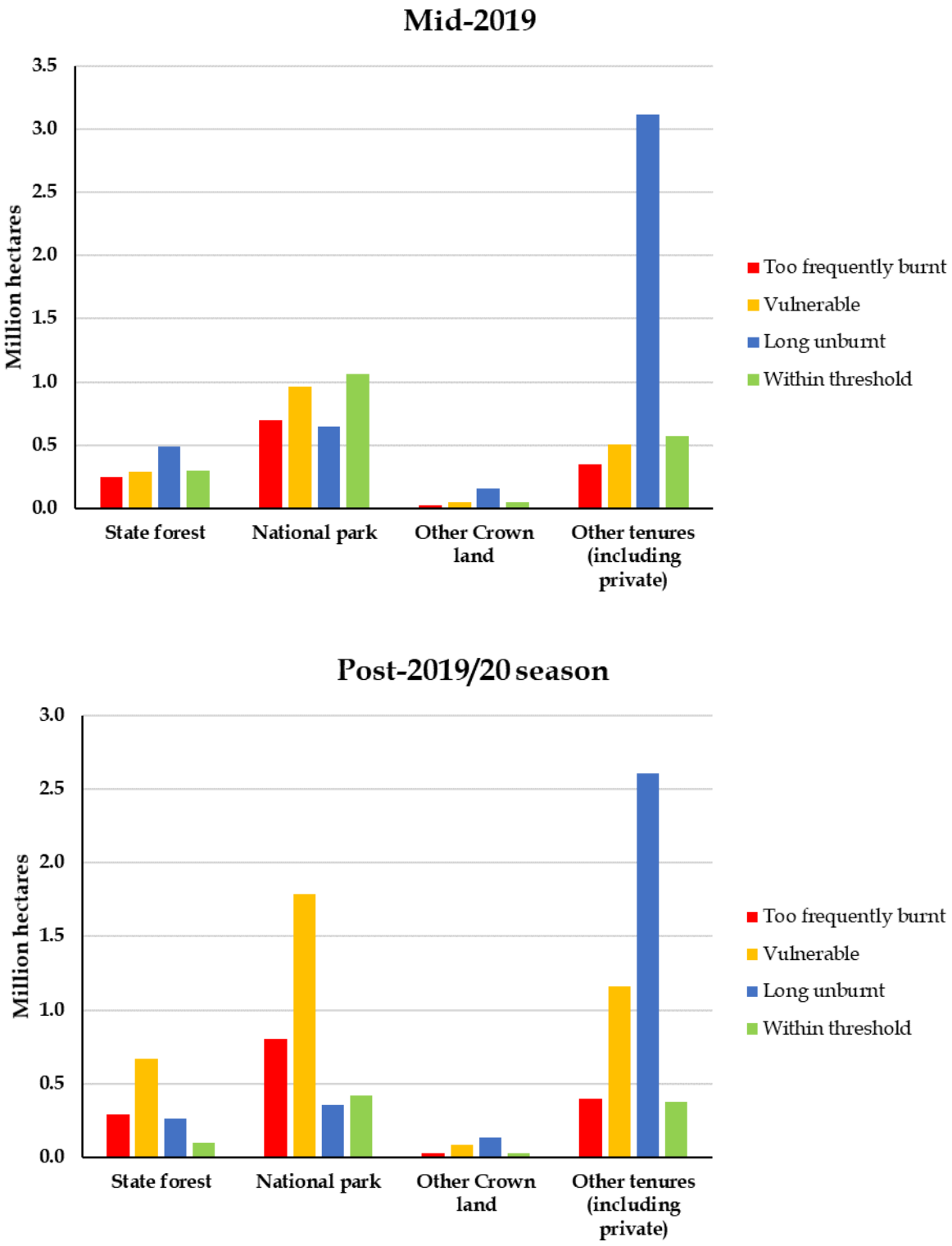

Figure 17: Area of fire frequency threshold categories by land tenure within the forested portion of the Coastal IFOA domain before (mid-2019) and after the 2019/20 fire season

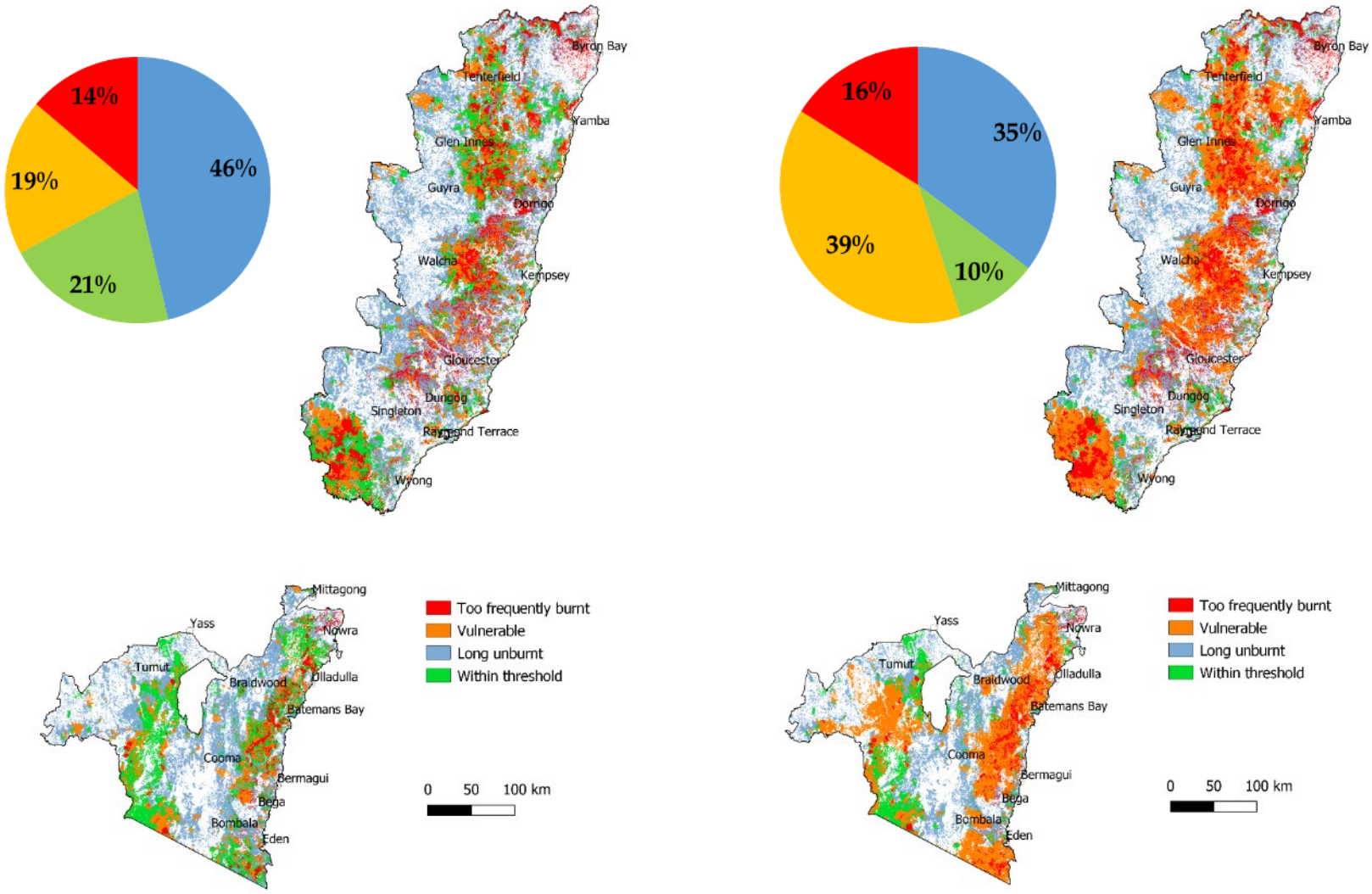

Figure 18: Change in fire frequency thresholds for flora pre-2019/20 wildfire (left) and post-2019/20 wildfire (right)

Soil, water quality, and aquatic impacts

Burned landscapes are susceptible to erosion and streamflow variation,[206] which can have implications for aquatic environments.[207, 208] The amount of sedimentation is significantly and positively related to the proportion of a catchment burnt.[209] Fire can also reduce fuel and soil organic nutrient pools through several processes, including oxidation and leaching. Soil nutrients may respond differently to these processes, but certain nutrients such as carbon, sulphur and nitrogen are particularly susceptible to fire-related losses.[210]

High-intensity fire makes soils susceptible to erosion in several ways, including enhanced water repellence of soils, which increases the risk of soil movement during high intensity rainfall events.[211] However, studies show different sediment generation processes occur in eucalypt forests. For example, following wildfire in the dry forests of Nattai National Park in NSW, a study found that most of the sediment that entered the stream network originated from ridgetops and steep side slopes.[212] In contrast, sediment generation was greater in the riparian zone in steep, wet montane ash forests in Victoria following intense wildfire in 2003.[213] These studies point to the importance of understanding how different soils and forests respond after fire including the dominant processes for sediment generation. Short-term impacts on vegetated groundcover increases the risk of soil movement and erosion.[214]

The 2019/20 wildfires and subsequent intense rainfall events are very likely to have caused an increase in erosion and connectivity between roads and waterways, resulting in sedimentation of waterways.[215] The EPA advised the Commission that wildfires may also have increased the risk of slumping and mass movement of soil. The magnitude of impacts is likely to vary with soil properties, post-fire vegetation recovery rates, forest road density and hillslope erosion

206 DeLong, S.B. Youberg, A.M. DeLong, W.M. and Murphy, B.P. (2018) 'Post-wildfire landscape change and erosional processes from repeat terrestrial lidar in a steep headwater catchment, Chiricahua Mountains, Arizona, USA'. *Geomorphology*, 300: 13-30.

207 Malison, R.L. and Baxter, C.V. (2010) 'The fire pulse: wildfire stimulates flux of aquatic prey to terrestrial habitats driving increases in riparian consumers'. *Canadian Journal of Fish and Aquatic Sciences*, 67: 570–579.

208 Emelko, M.B., Stone, M., Silins, U., Allin, D., Collins, A.L., Williams, C.H.S., Martens, A.M. and Bladon, K.D. (2016) 'Sediment-phosphorus dynamics can shift aquatic ecology and cause downstream legacy effects after wildfire in large river systems'. *Global Change Biology*, 22: 3.

209 Wilkinson, S.N., Wallbrink, P.J., Hancock, G., Blake, W., Shakesby, R. and Doerr, S. (2007) *Impacts on Water Quality by Sediments and Nutrients Released During Extreme Bushfires: Report 4: Impacts on Lake Burragorang*, CSIRO Land and Water Science Report for the Sydney Catchment Authority. Available at: https://publications.csiro.au/rpr/download?pid=procite:be24bf38-b8b2-486d-a697-315f78991b11&dsid=DS1.

210 Tulau, M.J. (2015) *Fire and Soils. A review of the potential impacts of different fire regimes on soil erosion and sedimentation, nutrient and carbon cycling, and impacts on water quantity and quality*. Office of Environment and Heritage. Available at: https://www.environment.nsw.gov.au/~/media/6676FDEC72B546F5B849301424B29835.ashx.

211 Shakesby, R.A., Wallbrink, P.J., Doerr, S.H., English, P.M., Chafer, C.J., Humphreys, G.S., Blake, W.H., and Tomkins, K.M. (2007) 'Distinctiveness of wildfire effects on soil erosion in south-east Australian eucalypt forests assessed in a global context'. *Forest Ecology and Management* 238: 347–364.

212 Blake, W.H., Wallbrink, P.J., Wilkinson, S.N., Humphreys, G.S., Doerr, S.H., Shakesby, R.A. and Tomkins, K.M. (2009) 'Deriving hillslope sediment budgets in wildfire-affected forests using fallout radionuclide tracers'. *Geomorphology*. 104: 105-116.

213 Sheridan, G.J., Lane, P.N.J. and Noske, P.J. (2007) Quantification of hillslope runoff and erosion processes before and after wildfire in a wet Eucalyptus forest. *Journal of Hydrology*, 343: 12-28.

214 Shakesby, R.A., Wallbrink, P.J., Doerr, S.H., English, P.M., Chafer, C.J., Humphreys, G.S., Blake, W.H., and Tomkins, K.M. (2007) 'Distinctiveness of wildfire effects on soil erosion in south-east Australian eucalypt forests assessed in a global context'. *Forest Ecology and Management* 238: 347–364.

215 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

processes. The overall magnitude of sedimentation and short- and long-term impacts on aquatic ecosystems across the fire-affected area is unknown.[216]

Heavy rainfall in January and February 2020 following the wildfires resulted in several observations of large fish kills in the hundreds or thousands of individuals or deaths of aquatic fauna in freshwater and estuarine reaches of NSW catchments downstream of fire-affected areas.[217] The highest number of species killed in one event (eight species killed) was documented in the Macleay River in northeast NSW with thousands of individual deaths, and these events were believed to be the first record, globally, of fire events extending to, and impacting estuaries through the mortality of obligate estuarine species.[218] The extension of the observed effects of fire to freshwater and estuarine systems is more far-reaching downstream than previously thought, with, for example, impacts extending down the Macleay River approximately 54 kilometres.[219]

DPI Fisheries advised the Commission that several aquatic species have been impacted by the 2019/20 wildfires, including a significant area of the predicted range of the Australian grayling (*Prototroctes maraena*) and Clayton's spiney crayfish (*Euastacus claytoni*).[220]

Modelling in several studies provides some insight, estimating post-fire sediment loads between 7[221] and 30[222] times greater than pre-fire rates. This illustrates how site characteristics influence sediment transfer and the likely high variability in erosion, connectivity and sedimentation rates across the landscape. Increased sedimentation can significantly impact aquatic ecosystems and drinking water through the generation of nutrient rich sediment slugs that can degrade fish habitat and trigger toxic algae blooms,[223] causing localised fish kills[224] and changes to macroinvertebrate assemblages.[225] Impacts can extend beyond freshwater reaches

216 *Ibid*.

217 Silva, L.G.M., Doyle, K.E., Duffy, D., Humphries, P., Horta, A. and Baumgartner, L.J (2020) 'Mortality events resulting from Australia's catastrophic fires threaten aquatic biota: letter to the editor.' *Global Change Biology*, 26:5345–5350.

218 *Ibid.*

219 *Ibid.*

220 DPI (2020) *Threatened fish species in NSW affected by the bushfires of summer 2019-20 - A synthesis of impacts, immediate actions and recovery priorities*. Unpublished report provided to the Commission for this review.

221 Joehnk, K. Biswas, T.K. Karim, F. Kumar, A. Guerschman, J. Wilkinson, S. Rees, G. McInerney, P. Zampatti, B. Sullivan, A. and Nyman, P. (2020) *Water quality responses and mitigation options for post 2019-20 wildfires floods in south eastern Australia – a catchment scale analysis*, p. 62. A Technical Report for the CSIRO Strategic Wildfire Project. Available at: https://www.researchgate.net/publication/345699893_Water_quality_responses_and_mitigation_options_for_post_2019-20_bushfires_floods_in_south_eastern_Australia_-_a_catchment_scale_analysis_A_Technical_Report_for_the_CSIRO_strategic_bushfire_project_202.

222 *Ibid* and Yang, X. Zhang, M. Oliveira, L. Ollivier, Q.R. Faulkner, S. and Roff, A. (2020) 'Rapid Assessment of Hillslope Erosion Risk after the 2019–2020 Wildfires and Storm Events in Sydney Drinking Water Catchment'. *Remote Sensing*, 12: 3805.

223 Alexandra, J. and Finlayson, C.M. (2020) 'Floods after wildfires: rapid responses for reducing impacts of sediment, ash, and nutrient slugs'. *Australasian Journal of Water Resources*, 24: 9-11.

224 Joehnk, K. Biswas, T.K. Karim, F. Kumar, A. Guerschman, J. Wilkinson, S. Rees, G. McInerney, P. Zampatti, B. Sullivan, A. and Nyman, P .(2020) *Water quality responses and mitigation options for post 2019-20 wildfires floods in south eastern Australia – a catchment scale analysis*, p. 62. A Technical Report for the CSIRO Strategic Wildfire Project. Available at: https://www.researchgate.net/publication/345699893_Water_quality_responses_and_mitigation_options_for_post_2019-20_bushfires_floods_in_south_eastern_Australia_-_a_catchment_scale_analysis_A_Technical_Report_for_the_CSIRO_strategic_bushfire_project_202.

225 Emelko, M.B., Stone, M., Silins, U., Allin, D., Collins, A.L., Williams, C.H.S., Martens, A.M. and Bladon, K.D. (2016) 'Sediment-phosphorus dynamics can shift aquatic ecology and cause downstream legacy effects after wildfire in large river systems'. *Global Change Biology*, 22: 3.

into estuarine and marine environments as ash and sediment move down through the catchment.

While the relationship between post-fire sedimentation rates and altered water quality are well-documented, there are significant knowledge gaps related to the NSW context, including in the understanding of which areas are vulnerable to post-fire erosion and water quality impacts. There is also uncertainty around the recovery time for instream biota and food webs to pre-fire conditions.[226]

Forest carbon impacts

Fires have direct impacts on forest carbon stocks immediately through combustion and release of greenhouse gases and progressively through decay and physical movement from the site. Initially, wildfire reduces fine-scale carbon pools, including litter and small woody debris, but these pools often recover quickly, particularly in fire-adapted forests.[227, 228] High severity fires can shift all or some of the carbon stocks from trees, which generally store the majority of aboveground carbon – approximately 70 percent[229] – to dead standing trees and large coarse woody debris.[230, 231] Eventually, as dead standing trees collapse, carbon stocks shift to coarse woody debris.[232] Forest carbon stocks increase over time as forests regenerate.

In fire-prone forests, the post-fire distribution of carbon stocks is dependent on the fire response traits of the dominant tree species. Wildfires cause a six-time greater loss of carbon stocks in non-resprouting than in resprouter eucalypt forests in southeast Australia.[233] In forests dominated by epicormic resprouters, carbon is thought to be rapidly reabsorbed back into the system.[234] However, in the short term, the change in carbon pools from fire-resistant live trees to dead standing trees, coarse woody debris, and more vulnerable smaller trees may result in

226 Joehnk, K. Biswas, T.K. Karim, F. Kumar, A. Guerschman, J. Wilkinson, S. Rees, G. McInerney, P. Zampatti, B. Sullivan, A. and Nyman, P. (2020) *Water quality responses and mitigation options for post 2019-20 wildfires floods in south eastern Australia – a catchment scale analysis*, p. 62. A Technical Report for the CSIRO Strategic Wildfire Project. Available at: https://www.researchgate.net/publication/345699893_Water_quality_responses_and_mitigation_options_for_post_2019-20_bushfires_floods_in_south_eastern_Australia_-_a_catchment_scale_analysis_A_Technical_Report_for_the_CSIRO_strategic_bushfire_project_202.

227 Kishchuk, B., Thiffault, E., Lorente, M., Quideau, S., Tim, K. and Derek, S. (2014) 'Decadal soil and stand response to fire, harvest, and salvage-logging disturbances in the western boreal mixed wood forest of Alberta (Canada)'. *Canadian Journal of Forest Research*, 45: 141-152.

228 Peterson, D. W., Dodson, E. K. and Harrod, R. J. (2015) 'Post-fire logging reduces surface woody fuels up to four decades following wildfire'. *Forest Ecology and Management*, 338: 84-91.

229 Fedrigo, M., Kasel, S., Bennett, L. T., Roxburgh, S. H. and Nitschke, C. R. (2014) 'Carbon stocks in temperate forests of south-eastern Australia reflect large tree distribution and edaphic conditions'. *Forest Ecology and Management*, 334: 129-143.

230 Kauffman, J. B., Ellsworth, L. M., Bell, D. M., Acker, S. and Kertis, J. (2019) 'Forest structure and biomass reflects the variable effects of fire and land use 15 and 29 years following fire in the western Cascades, Oregon'. *Forest Ecology and Management*, 453: 117570.

231 Bassett, M., Leonard, S.W.J., Chia, E.K., Clarke, M.F. and Bennett, A.F. (2017) 'Interacting effects of fire severity, time since fire and topography on vegetation structure after wildfire'. *Forest Ecology and Management*, 396: 26-34.

232 Peterson, D. W., Dodson, E. K. and Harrod, R. J. (2015) 'Post-fire logging reduces surface woody fuels up to four decades following wildfire'. *Forest Ecology and Management*, 338: 84-91.

233 Wilson, N., Bradstock, R. and Bedward, M. (2021) 'Comparing forest carbon stock losses between logging and wildfire in forests with contrasting responses to fire'. *Forest Ecology and Management*, 481: 118701.

234 Pausas, J.G., and Keeley, J.E. (2017) 'Epicormic resprouting in fire-prone ecosystems'. *Trends in Plant Science*, 22: 1008-1015.

greater carbon instability in the face of cumulative disturbances.[235, 236] This shift in carbon pools is greater in forests burned at high severity.[237, 238, 239]

The literature review confirmed there were no studies directly related to the impacts of the 2019/20 fires on carbon stocks in NSW. Consequently, the Commission, through the NSW Forest Monitoring and Improvement Program, has engaged a team to quantify the impact of the 2019/20 wildfires on forest carbon. Results are expected to be available later in 2021.

6.2 There is early evidence that recovery is underway

As discussed in **Section 6.1**, the 2019/20 wildfires were extensive and significantly and negatively impacted ecosystems and species. While forests and forest dependent species possess traits that enable them to persist or regenerate following fire, the rate at which recovery will occur following such extensive and severe fires is uncertain and dependent on many biotic and abiotic factors.[240] Biotic factors are living organisms, such as plants and animals, that affect or influence the ecosystem in which they live. Abiotic factors are non-living things and include light availability, soil and air temperature, soil nutrients and water availability.

There is a reasonable body of existing literature on the recovery rates of some NSW flora and fauna species after fire or disturbance. This information can be used to predict or inform the possible ranges in recovery times for species that have been studied. In addition, NSW agencies have been collecting post-fire data to improve knowledge on the impacts of the 2019/20 wildfires and how flora and fauna are recovering. This data includes remote sensing imagery and field surveys.

While field monitoring provides important site-based data on a range of ecosystems elements, the very large area of fire-affected forest makes it difficult to comprehensively survey the impacts on some elements, such as vegetation recovery. Further, there are significant safety issues in burnt forests that make field surveys potentially dangerous for workers. Remote sensing is a practical, repeatable, scientifically credible and cost-effective way to map burnt areas and analyse broad-scale post-fire forest recovery over time.[241, 242]

The Coastal IFOA objectives and outcomes, and the forestry prescriptions to achieve them, were developed prior to the 2019/20 wildfires. Wildfires of such magnitude were not envisaged or planned for in the Coastal IFOA. Tracking recovery of forest health will help understand how

235 Bennett, L.T., Bruce, M.J., Machunter, J., Kohout, M., Krishnaraj, S.J. and Aponte, C. (2017) 'Assessing fire impacts on the carbon stability of fire-tolerant forests'. *Ecological Applications*, 27: 2497-2513.

236 Hurteau, M. D. and Brooks, M. L. (2011). 'Short- and Long-term Effects of Fire on Carbon in US Dry Temperate Forest Systems'. *BioScience*, 61(2): 139-146.

237 Bennett, L.T., Aponte, C., Baker, T.G. and Tolhurst, K.G. (2014) 'Evaluating long-term effects of prescribed fire regimes on carbon stocks in a temperate eucalypt forest'. *Forest Ecology and Management*, 328: 219-228.

238 Bennett, L.T., Bruce, M.J., Machunter, J., Kohout, M., Krishnaraj, S.J. and Aponte, C. (2017) 'Assessing fire impacts on the carbon stability of fire-tolerant forests'. *Ecological Applications*, 27: 2497-2513.

239 Burton, J.E., Bennett, L.T., Kasel, S., Nitschke, C.R., Tanase, M.A., Fairman, T.A., Parker, L., Fedrigo, M. and Aponte, C. (2021) 'Fire, drought and productivity as drivers of dead wood biomass in eucalypt forests of south-eastern Australia'. *Forest Ecology and Management*, 482: 118859.

240 Bell, D.T. (1999) 'The process of germination in Australian species'. *Australian Journal of Botany*, 47: 475-517.

241 Gibson, K.R. and Hislop, S. (MS) *Signs of resilience in resprouting Eucalyptus forests, but areas of concern: One year of post-fire recovery from Australia's Black Summer 0f 2019-20.* Submitted to PNAS.

242 Chuvieco, E. *et al*. (2019) 'Historical background and current developments for mapping burned area from satellite Earth observation'. *Remote Sensing of Environment*, 225: 45-64.

temporary measures and standard prescriptions can effectively manage risks to achieving Coastal IFOA objectives and outcomes.

This section presents available information on the predicted and observed recovery of forests and forest dependent species following the 2019/20 wildfires. This body of evidence will continue to grow as NSW agencies and other organisations continue to collect and analyse monitoring data.

Literature and predictive models provide insights into possible recovery rates of forests

The way plants respond to and regenerate after fire influences ecosystem composition and function.[243] Australian plants are commonly classified as resprouters or obligate seeders in relation to their adaptation to fire. Resprouters are plants that are able to survive fire, even if all their foliage is consumed, by vegetatively resprouting new shoots from aerial, basal and below-ground buds[244] or resprouting from pre-bud meristems protected by thick bark (epicormic resprouting).[245] In contrast, obligate seeders are plants that are killed by fire but regenerate prolifically from seed in the soil ash bed, and require fire-free intervals to enable their critical life history traits of plant growth, flowering, seed set, maturation and senescence.[246] Forest communities dominated by epicormic resprouters are highly resistant to shifts in fire regime.[247]

The forests of the Coastal IFOA are dominated by eucalypts, most of which have the capacity to resprout following fire.[248] The relative recovery potential of forest types in the Coastal IFOA region is influenced by the vegetation's susceptibility to fire scorch, predominant regeneration strategy following fire, the landscape context and forecast climate.[249] **Figure 19** illustrates the post-fire relative recovery potential of forest leagues in the Coastal IFOA, and shows that forests of the south coast region dominated by alpine ash are more likely to have a relative lower recovery potential. Forest types on the north coast are more likely to have a relatively high recovery potential.

Preliminary modelling conducted by DPI Forest Science has predicted recovery of burnt areas in the north coast to be much quicker than the south coast.[250]

243 Clarke, P.J., Lawes, M.J., Murphy, B.P., Russell-Smith, J., Nano, C.E.M., Bradstock, R., Enright, N.J., Fontaine, J.B., Gosper, C.R., Radford, I., Midgely, J.J. and Gunton, R.M. (2015) 'A synthesis of postfire recovery traits of woody plants in Australian ecosystems'. *Science of the Total Environment*. 534: 31-42.

244 Clarke, P.J., Lawes, M.J., Midgley, J.J., Lamont, B.B., Ojeda, F., Burrows, G.E., Enright, N.J. and Knox, K.J.E. (2013) 'Resprouting as a key functional trait: how buds, protection and resources drive persistence after fire'. *New Phytologist*. 197: 19–35.

245 Clarke, P.J., Lawes, M.J., Murphy, B.P., Russell-Smith, J., Nano, C.E.M., Bradstock, R., Enright, N.J., Fontaine, J.B., Gosper, C.R., Radford, I., Midgely, J.J. and Gunton, R.M. (2015) 'A synthesis of postfire recovery traits of woody plants in Australian ecosystems'. *Science of the Total Environment*. 534: 31-42.

246 Bowman, D.M.J.S., Murphy, B.P., Neyland, D.L.J., Williamson, G.J. and Prior, L.D. (2014) 'Abrupt fire regime change may cause landscape-wide loss of mature obligate seeder forests'. *Global Change Biology*. 20: 1008-1015.

247 Collins, L. (2019) 'Eucalypt forests dominated by epicormic resprouters are resilient to repeated canopy fires'. *Journal of Ecology*. 108: 310–324.

248 Analysis presented in Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

249 *Ibid*.

250 DPI Forest Science (2021) *A preliminary model of predicted years to post-fire spectral recovery for the 2019/20 fires*. This product is still under research and development and not peer reviewed. The preliminary analysis was provided to the Commission to support priority Coastal IFOA inquiries. DPI used predicted spectral recovery of the forest canopy to the pre-fire reflectance. This is modelled recovery using a variety of variables, including fire extent and severity mapping severity class and climate.

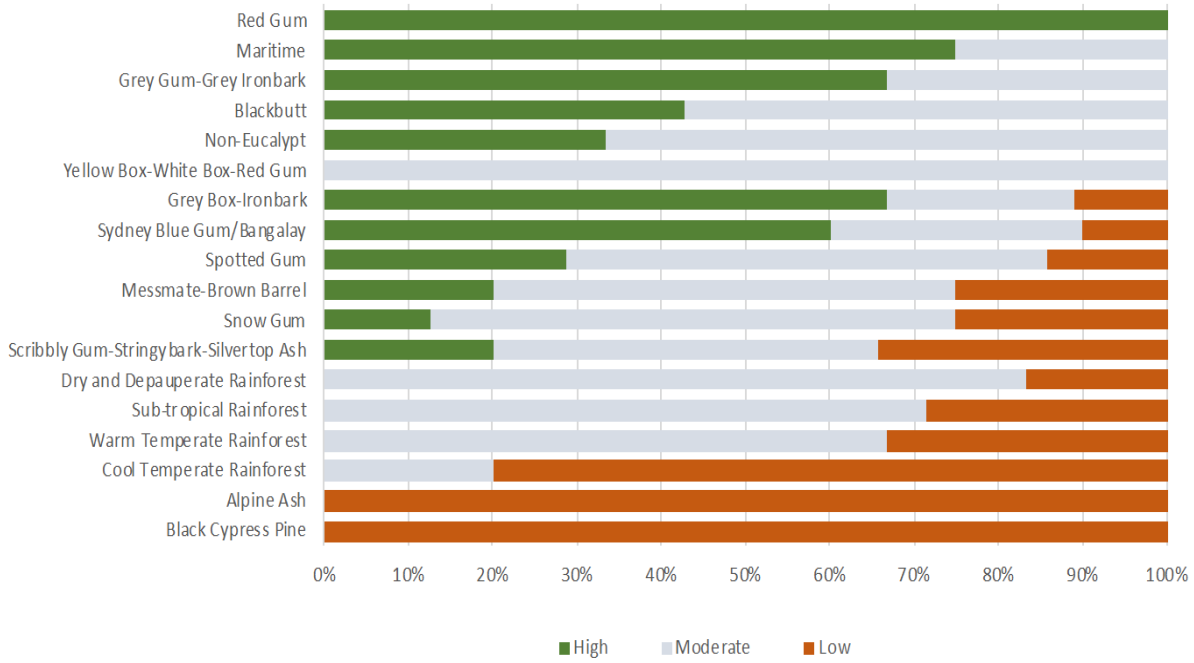

Figure 19: Estimated proportion of forest types in each forest league within the high, moderate and low recovery potential class[251]

On-ground monitoring shows signs of flora and fauna recovering

Recovery will take time and different flora and fauna species will recover at very different rates. Some species have the capacity to recover quickly following fire (for example eucalyptus species that resprout), while others are highly susceptible and slow to recover (for example, arboreal mammals).

While literature and remote sensing provides insights into and indicators of ecosystem recovery, on-ground monitoring plays an important role in understanding how individual species or ecosystems are recovering. NSW agencies, non-government organisations and community groups are conducting post-fire surveys across the areas impacted by the 2019/20 wildfires.

Figures 20-24 show photographs taken from permanent photo points in the state forest estate established after the 2019/20 wildfires. They illustrate impacts associated with different fire severity and recovery in different Coastal IFOA regions. These photographs show very little or no groundcover existed post severe fire, and over time, groundcover, understorey and resprouting species are recovering. FCNSW advised that recovery across the south coast is variable, but there are large areas where initial rates of recovery are high.

Evidence of fauna species remaining in and returning to fire-affected areas is becoming available, with some of this information published. This section briefly describes some observations of species persisting or recolonising the burnt landscape.

The DPI Forest Science unit monitored koalas at 16 burnt sites on state forests with varying degrees of severity and fire extent. In general, post-fire koala occupancy in areas with low- to

251 Analysis presented in Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

moderate severity fires was similar to occupancy in unburnt habitat However, there were reductions in areas with high to extreme severity fires. While koalas were recorded in areas that experienced high severity fire, they were not recorded in the areas where high severity fires were also widespread. This analysis only described koala occupancy, not density at a site. While findings are encouraging, researchers expect many occupied sites experienced a severe decline in koala density.[252]

Other findings from recent monitoring are listed below:

- 77 greater gliders found in burnt and unburnt sites in Mount Kaputar in May 2020[253] and smoky mouse (*Pseudomys fumeus*) in 7 burnt sites in Kosciuszko National Park.[254]
- The return of many frog species post-fire (45 of the 66 frog species detected prior to the fires were present at least 125 days post-fire and all frog species with more than five pre-fire records were present within 125 days post-fire).[255]
- A total of 2,840 flora and fauna species were recorded during 739 surveys in burnt and unburnt state forests in the South Coast and Eden subregions after the 2019/20 wildfires (collected between late November 2019 to early February 2020), including many non-threatened species and threatened species (such as the southern brown bandicoot, (*Isoodon obesulus*), long-nosed potoroo, long-nosed bandicoot (*Perameles nasuta*), greater glider, swift parrot (*Lathamus discolor*), northern corroboree frog (*Pseudophryne pengilleyi*), glossy black cockatoo (*Calyptorhynchus lathami*), varied sitella (*Daphoenositta chrysoptera*), Littlejohn's tree frog (*Litoria littlejohni*), yellow-bellied glider, and the East Lynne midge orchid (*Genoplesium vernale*).[256]

While these limited findings indicate that for some species and some locations recovery may be underway, more research is needed to understand species responses across multiple scales.[257]

252 DPI (2021) *Koala research in NSW forests*. Available at: https://www.dpi.nsw.gov.au/forestry/science/koala-research.

253 DPIE (2021) *NSW Wildlife and Conservation Bushfire Recovery - Medium-term response plan.* Available at: environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/nsw-wildlife-and-conservation-bushfire-recovery-medium-term-response-plan-200478.pdf.

254 DPIE (2021) *NSW Wildlife and Conservation Bushfire Recovery Supplement A – Assessing the impact of the bushfires on wildlife and conservation.* Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/nsw-wildlife-and-conservation-bushfire-recovery-supplement-a-assessing-impact-200478.pdf?la=en&hash=48FD9D59E1C43B947E6C56A3709725992927A427.

255 Rowley, J.L., Callaghan, C.T. and Cornwell, W.K. (2020) 'Widespread short-term persistence of frog species after the 2019–2020 wildfires in eastern Australia revealed by citizen science'. *Conservation Science and Practice*, 2: e287.

256 FCNSW (2021) *Post-fire Ecology survey summary for the Southern and Eden subregions*. Unpublished document provided to the Commission for this review.

257 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

Urunga Management Zone

Mistake State Forest – Ingalba Local Landscape Area

Dry sclerophyll forest

FESM class: Extreme

RAFIT class: Crowned and complete

31 January 2020

25 March 2020

27 April 2020

11 May 2020

24 June 2020

30 July 2020

Figure 20: Permanent photo point data – Mistake State Forest (provided by FCNSW)

Casino Management Zone

Gibberagee State Forest – Banyabba Station Local Landscape Area

Dry sclerophyll forest

FESM class: High

RAFIT class: Crowned and complete

31 January 2020

25 March 2020

27 April 2020

11 May 2020

24 June 2020

30 July 2020

Figure 21: Permanent photo point data – Gibberagee State Forest (provided by FCNSW)

Coffs Harbour Management Zone

Kangaroo River State Forest – Haystack Local Landscape Area

Dry sclerophyll forest

FESM class: Low

RAFIT class: Hot burn, but not crowned

28 January 2020

19 March 2020

28 April 2020

28 May 2020

28 July 2020

13 October 2020

Figure 22: Permanent photo point data – Kangaroo River State Forest (provided by FCNSW)

Batemans Bay Management Zone

Mogo State Forest – Mogo 4 Local Landscape Area

Dry sclerophyll forest

FESM class: Extreme

RAFIT class: Crowned and complete

20 February 2020

16 March 2020

26 March 2020

3 April 2020

28 April 2020

3 June 2020

Figure 23: Permanent photo point data – Mogo State Forest (provided by FCNSW)

Batemans Bay Management Zone

Wandera State Forest – Wandera 2 Local Landscape Area

Dry sclerophyll forest

FESM class: High

RAFIT class: Hot burn, not crowned

20 February 2020

16 March 2020

26 March 2020

5 April 2020

28 April 2020

5 June 2020

Figure 24: Permanent photo point data – Wandera State Forest (provided by FCNSW)

6.3 Fire regimes have shifted and increased risks

The 2019/20 fire resulted in major shifts in fire regimes (**Figure 17** and **Figure 18**), and fire frequency patterns that indicate more than half of the vegetation in the forested portion of the Coastal IFOA may be prone to a decline in plant diversity.[258]

Extreme disturbance regimes such as high frequency of fire, long-term absence of fire and high intensity of fire can pose risks to the objectives and outcomes of the Coastal IFOA.[259] This is because they have the potential to fundamentally alter the ecological structure and function of the forest and result in the loss of features that different fauna and flora species depend on. Prior to the 2019/20 wildfires the analysis conducted for this review shows evidence that both extreme fire frequencies across the Coastal IFOA region and a large proportion of all land tenure categories remained long unburnt.[260]

As discussed in **Section 6.1**, the 2019/20 wildfires:

- effectively doubled the area exposed to high frequency fire, including about 25 percent of state forests and national park estate
- created heightened vulnerability to future wildfires, reflected in major changes in the time since fire with more than half of state forests and national park now in the less than five years since last fire category
- partially reduced the area that was long unburnt (about 10% reduction)
- greatly elevated risk to achieving the Coastal IFOA objectives and outcomes, particularly in the short-term over the next five to ten years.

The key implications to Coastal IFOA objectives and outcomes from the 2019/20 wildfires relate to maintaining ecological function and habitat connectivity, with relevance to maintenance of species, positioning of harvesting operations, and water quality. This includes:[261]

- Around 20 to 30 percent of the area of ridges and upper slopes, and also valleys and lower slopes were exposed to the highest levels of fire severity in state forests and the national park estate, in approximately equal measure. This means that key areas such as riparian zones, wet forest refugia, young post-harvest regrowth and soil and slope combinations prone to erosion have potentially been affected to a major degree.
- The large areas of the main sclerophyll forest formations in national parks and state forests are likely to have resulted in the loss of hollow bearing trees, compromised regeneration in areas burnt and/or logged shortly before 2019/20 fires, carbon loss and the exposure of wet sclerophyll forest refugia to burning.
- The area affected and fire regime patterns across the public land categories of state forests and national parks were similar, spreading the burden of risk equally across these land tenures.
- Fire severity patterns across harvested state forests indicate a high level of potential impact on forest regeneration, structure and habitat values. This includes exposure to

258 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

259 *Ibid.*

260 *Ibid.*

261 *Ibid.*

crown-damaging fires (high and extreme severity) particularly in dry and wet sclerophyll forest formations. Harvesting has mostly been focussed on these forest formations in the last 20 years. These impacts may be relatively long lasting, particularly given the magnitude of the fires.

- However, the analysis did not show a strong difference in proportion burnt and exposure to different fire severity levels across both recently harvested (2014 to 2019) or longer term harvested (2000 to 2019) areas, concluding that the overwhelming factor that appears to have governed patterns of burning across major vegetation formations, land tenure types was the extremity of drought and unrelenting nature of elevated fire weather during the 2019/20 season.
- The Coastal IFOA contains a significant area of potential suitable habitat for the group of threatened animal species investigated in the analysis, of which a large proportion was burnt, and further large areas were also exposed to high and extreme severity fire. This exposure is assumed to have had adverse effects on species occupancy and habitat suitability, especially as 13 of the 24 species considered are listed as being dependent on hollows and logs, five are dependent on dense understorey and several species rely on nectar or specific feed plants.
- While the overall proportion of the area of harvested predicted habitat that burned in 2019/20 within the forested portion of the CIFOA was relatively low (less than 7 percent), compounding effects of these disturbances may have been acute. Given the size of the fires, their overlay across dispersed pockets of recent harvesting may have diminished connectivity of suitable potential habitat in the short term.
- Persistence of these effects is likely to be variable. Losses of hollow bearing trees may require many decades until replacement, though the severity of these fires may have increased the likelihood of new hollow development. By contrast loss of dense grassy habitat (for example, Southern Brown-Nosed Bandicoot) or open understorey (for example, White Footed Dunnart) may be short-lived or possibly promoted by these widespread fires, particularly in areas that have experienced regular burning.

In summary, the elevated risks to Coastal IFOA objectives and outcomes primarily result from the compounding effects of the very large area burnt in 2019/20, the relatively high area burnt by severe fires and the resultant area exposed as high frequency wildfire hotspots.

6.4 Extensive fire-affected landscapes may be the new normal

The extreme fire conditions associated with the 2019/20 wildfires arose largely as a result of extended drought and heat driven by El Niño conditions leading into the spring-summer season,[262] followed by periods of hot, windy weather with little rainfall in spring-summer.[263]

Bureau of Meteorology data show that 2019 was the warmest year on record, with a mean national maximum temperature of 1.59 degrees Celsius above the long-term average. All years from 2013 to 2018 have also been included in the 10 warmest years on record in Australia.[264]

262 Adams, M.A., Shadmanroodposhti, M. and Neumann, M. (2020) 'Causes and consequences of Eastern Australia's 2019–20 season of mega-fires: A broader perspective'. *Global Change Biology.* 26: 3756-3758.

263 Boer, M.M., de Rois, V.C. and Bradstock, R.A. (2020) 'Unprecedented burn area of Australian mega forest fires'. *Nature Climate Change.* 10: 171-172.

264 Filkov, A.I., Ngo, T., Matthews, S., Telfer, S. and Penman, T.D. (2020) 'Impact of Australia's catastrophic 2019/20 bushfire season on communities and environment. Retrospective analysis and current trends'. *Journal of Safety Science and Resilience.* 1: 44-56.

2019 was also the driest on record for Australia, with the national total rainfall (277.6 millimetres) about 40 percent below the 1961-1990 average. In August 2019 (the start of the fire period) nearly all of NSW was drought-affected, with 17 percent experiencing intense drought.[265] The drought was associated with surface temperatures in the Indian and Pacific oceans impacting rain-bearing winds[266] and resulting in a 30-year low in eucalyptus leaf litter moisture levels along Australia's east coast.[267]

Hydroclimatic analysis found that ongoing drought, surface soil moisture, wind speed, relative humidity, heat waves, dead and live fuel moisture, and certain land cover types created favourable conditions for fire ignition and aided in fire propagation in different regions of NSW.[268] The unprecedented nature of the 2019/20 wildfires and the corresponding severe and widespread landscape dryness point to climate change as the overriding influence on this fire event.[269] There is now evidence that the impacts of wildfires in Australia and globally have been made considerably worse by the effects of climate change to date, with contemporary weather conditions, such as heatwaves, highly unlikely to have occurred in the absence of climate change.[270]

Eastern Australia has recently experienced a moderate La Niña event, which brought wetter and cooler conditions to forested landscapes[271] and most likely assisted severely burnt forest to recover post-fire.[272] However, there is an increasing likelihood of more severe droughts[273] and more extreme fire weather in the future.[274, 275, 276, 277] Fire weather is weather that is conducive to the outbreak and spread of fire, and is typically expressed through some combination of surface

265 *Ibid.*

266 Bowman, D.M.J.S., Williamson, G.J., Price, O.F., Ndalila, M.N. and Bradstock, R.A. (2020) 'Australian forests, megafires and the risk of dwindling carbon stocks'. *Plant, Cell and Environment.* 2020: 1-9.

267 Nolan, R.H., Boer, M.M., Collins, L. Resco de Dios, V., Clarke, H., Jenkins, M., Kenny, B. and Bradstock, R.A. (2020) 'Causes and consequences of eastern Australia's 2019-20 season of mega-fires'. *Global Change Biology.* 26: 1039-1041.

268 Deb, P., Moradkhani, H., Abbaszadeh, P., Kiem, A. S., Engström, J., Keellings, D. and Sharma, A. (2020) 'Causes of the widespread 2019–2020 Australian bushfire season'. *Earth's Future.* 8: e2020EF001671.

269 Bradstock, R.A., Nolan, R.H., Collins, L., de Dios, V.R., Clarke, H., Jenkins, M., Kenny, B. and Boer, M.M. (2020) 'A broader perspective on the causes and consequences of eastern Australia's 2019–20 season of mega-fires: A response to Adams *et al*'. *Global Change Biology.* 26: e8-e9; van Oldenborgh, G.J., Krikken, F., Lewis, S., Leach, N.J., Lehner, F., Saunders, K.R., van Weele, M., Haustein, K., Li, S., Wallom, D., Sparrow, S., Arrighi, S., Singh, R.P., van Aalst, M.K., Philip, S.Y., Vautard, R. and Otto, F.E.L. (2020) 'Attribution of the Australian bushfire risk to anthropogenic climate change'. *Natural Hazards and Earth System Sciences*. Available at: https://doi.org/10.5194/nhess-2020-69.

270 Lewis, S.C., Blake, S.A.P., Trewin, B., Black, M.T., Dowdy, A.J., Perkins-Kirkpatrick, S.E., King, A.D., and Sharples, J.J. (2020) 'Deconstructing factors contributing to the 2018 fire weather in Queensland, Australia'. *Bulletin of the American Meteorological Society*. 101: S115-S121.

271 Australian Bureau of Meterology (2021) *January 5 2021 update: La Niña has likely reached its peak but impacts likely through summer*. Available at: http://www.bom.gov.au/climate/enso/wrap-up/archive/20210105.archive.shtml.

272 Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

273 Fensham, R.J., Fraser, J., Macdermott, H.J. and Firn, J. (2015) 'Dominant tree species are at risk from exaggerated drought under climate change'. *Global Change Biology.* 21: 3777–3785.

274 Hasson, A.E.A., Mills, G.A., Timbal, B. and Walsh, K. (2009) 'Assessing the impact of climate change on extreme fire weather events over southeastern Australia'. *Climate Research.* 39: 159-172.

275 Jones, M.W., Smith, A., Betts, R., Canadell, J.G., Prentice, C.I., and Le Quéré, C. (2020) 'Climate change increases risk of wildfires'. *ScienceBrief Review.* Available at: https://sciencebrief.org/briefs/wildfires.

276 Smith, A.J.P., Jones, M.W., Abatzoglou, J.T., Canadell, J.G. and Betts, R.A. (2020) 'Climate change increases risk of wildfires'. *ScienceBrief Review.* Available at: https://news.sciencebrief.org/wildfires-sep2020-update/.

277 Sharples, J.J., Cary, G.J., Fox-Hughes, P., Mooney, S., Evans, J.P., Fletcher, M_S, Fromm, M., Grierson, P.F., McRae, R. and Baker, P. (2016) 'Natural hazards in Australia: extreme bushfire'. *Climatic Change.* 139: 85-99.

air temperature, precipitation, relative humidity and wind speed.[278] More extreme fire weather could include increased surface air temperatures, lower humidity and rainfall, greater wind speeds, or a combination of these.

Future climate projections include increases in the frequency or intensity of heat events, fire weather and drought when the El Niño–Southern Oscillation or the Indian Ocean Dipole favour warmer and drier conditions in Australia. This includes a trend of more frequent 'compound extreme events' where extreme events (such as fire and drought) occur concurrently or consecutively.[279] If drought continues after severe fire it is likely to result in increased tree mortality and reduce the capacity of forest ecosystems to regenerate and recover following subsequent fire events.[280]

Large-extent fires are increasing in occurrence

There is evidence that extreme fire seasons characterised by very large 'mega-fires' have increased the area burnt across forested regions globally.[281] There is also evidence that suggests the occurrence of large wildfires has increased across south-eastern Australia since the 1950s, with a strong potential for them to increase in frequency in the future.[282] The 2019/20 wildfires are an indication that fire regime predicted under climate change, including more frequent and more severe fires may now be occurring.[283] Analysis undertaken for the Commission reinforces the conclusion that the likely future trend is for increased fire danger and area burned by wildfires.[284]

While the 2019/20 fire season was unprecedented in terms of total extent and the extent of high severity burnt area, the proportion of high severity fire area was not greater than prior wildfire seasons between 1988 to 2020.[285]

Patterns in fire severity have a greater influence on biodiversity and ecosystem function than area burnt.[286] Severe fire can trigger widespread canopy foliage loss and branch, stem or whole

278 Clarke, H. (2015) *Climate Change Impacts on Bushfire Risk in NSW*. Report prepared for the Office of Environment and Heritage. Available at: https://climatechange.environment.nsw.gov.au/-/media/NARCLim/Files/Climate-Change-Impact-Reports/Climate-Change-Impacts-on-Bushfire-Risk-in-NSW.pdf?la=en&hash=070F5611F39C122D1223D26B3DA1B07E08AFCDA6.

279 CSIRO and BOM (2020) *State of the Climate 2020*. Available at: https://www.csiro.au/en/research/environmental-impacts/climate-change/state-of-the-climate#Downloadthereport.

280 As synthesised in Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

281 Collins, L, Bradstock, R.A., Clarke, H. Clarke, M.F., Nolan, R.H. and Penman, T.D. (2021) 'The 2019/20 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fires'. *Environmental Research Letters*, 16(4).

282 Sharples, J.J., Cary, G.J., Fox-Hughes, P., Mooney, S., Evans, J.P., Fletcher, M.S, Fromm ,M., Grierson, P.F., McRae, R. and Baker, P. (2016) 'Natural hazards in Australia: extreme bushfire'. *Climate Change* 139: 85–99.

283 Nolan, R. *et al*. (2020) Causes and consequences of eastern Australia's 2019–20 season of mega-fires: Letter to the editor. *Global Change Biology*, 26: 1039–1041.

284 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

285 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H., and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16: 044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.

286 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H., and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16: 044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.

plant mortality, causing substantial changes to ecosystem structure and function.[287] The fire severity class at which this occurs depends on the canopy species' resistance to fire,[288] and the size-specific susceptibility to fire-induced mortality of the tree species.[289] For most vegetation types across the Coastal IFOA region, impacts on ecosystem structure and function would occur at high to extreme fire severity, excluding rainforest where moderate to extreme fire severity could trigger this response.[290]

Forest areas that are unburnt or lightly burnt provide important refuges for species in the aftermath of fire.[291]

Regional climate projections

Regional climate projections for NSW provide insight into future climate (for the period 2060-2079) in the Coastal IFOA regions.[292] Analysis of these climate projections include that:

- coastal regions are likely to have significantly more rainfall throughout the year
- regions north of and including the Illawarra are projected to receive more rainfall in future (at least by the majority of models), while rainfall in the South-east and Tablelands and the Murray-Murrumbidgee regions (including the Alps) is likely to stay relatively unchanged
- northern regions have a higher proportion of rainfall falling in spring and summer (typical fire season) than southern regions
- while temperature increases are projected to be relatively consistent across all regions (generally 0.7 degrees Celsius by 2030 and 2.0 degrees Celsius by 2070), the proportional change will be more marked in areas that currently experience relatively low mean temperatures, notably south coast and high-elevation areas.[293]

These observations are broadly supported by results of a hydro-climatic analysis of conditions in NSW leading to the 2019/20 wildfires,[294] where:

- surface soil moisture and dead biomass fuel moisture were notably less in southern NSW compared with northern NSW
- relative humidity was notably less inland than in coastal regions
- heatwave conditions were more prevalent inland.

287 *Ibid.*
288 *Ibid.*
289 Trouvé, R., Oborne. L. and Baker P.J. (2021) 'The effect of species, size, and fire intensity on tree mortality within a catastrophic bushfire complex'. *Ecological Applications*, doi:10.1002/eap.2383.
290 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H., and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16: 044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.
291 As synthesised in Wall, J. (2021) *Wildfire Refugia.* 2rog Consulting. A report prepared for the Commission for this review.
292 DPIE (2020) *AdaptNSW.* Available at: https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region.
293 As synthesised in Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.
294 Deb, P., Moradkhani, H., Abbaszadeh, P., Kiem, A. S., Engström, J., Keellings, D. and Sharma, A. (2020) 'Causes of the widespread 2019–2020 Australian bushfire season'. *Earth's Future.* 8: e2020EF001671.

Despite this, wildfires in northern NSW were also severe in 2019/20, as the drought index for this part of NSW was relatively high and average windspeeds were also significantly higher prior to the wildfires.[295]

In general, based on NSW regional projections, Coastal IFOA regions are likely to continue to warm to an average projected 2 degrees Celsius above the pre-industrial average by 2070. The number of hot days (greater than 35 degrees Celsius) is predicted to increase, mainly in spring and summer and the number of cold nights (less than 2 degrees Celsius) is predicted to decrease, mainly in winter. Absolute temperature increases will be greater in inland areas compared with coastal areas. Fire weather is likely to increase for all regions in spring and summer, although this increase is more pronounced in inland and southern regions. This is because inland and southern regions experience a more even distribution in rainfall or winter-dominated rainfall, compared to the summer-dominated rainfall in the north coast and coastal Hunter regions. Projections indicate an amplified risk of multiyear drought matching or exceeding the intensity of the Millennium Drought.[296] Based on NSW Government climate modelling, severe fire weather is predicted to decrease in Autumn across all regions.[297]

While modelled climate projections are a useful guide, the scale of the 2019/20 fire season in NSW is unmatched by modelled increased fire activity under climate change in either the present or the future.[298] This means that the climate projections available may underestimate future fire activity and highlights the importance of a reassessment process that builds on monitoring data and an adaptive management approach. The Commission has developed the reassessment process to accommodate the potential for future extreme fire events, which it does through annual analysis of spectral recovery data. Further, the potential for future large-scale fire events reinforces the need for a new condition and protocol in the Coastal IFOA to respond to these events efficiently and effectively.

6.5 Future risks to Coastal IFOA objectives and outcomes will increase

The 2019/20 significantly changed disturbance regimes and the direction and magnitude of this change are likely to be reinforced in coming decades.[299] This means that the area of the Coastal IFOA that will be exposed to high frequency and high intensity wildfires is likely to increase substantially.[300]

Commensurate increases in risk to all the objectives and outcomes of the Coastal IFOA, such as water quality, forest regeneration and structure, carbon storage and threatened species

295 *Ibid*.

296 Cook, B.I., et al. (2016) The paleoclimate context and future trajectory of extreme summer hydroclimate in eastern Australia, *Journal of Geophysical Research: Atmospheres*, 121, 12,820–12,838, doi:10.1002/2016JD024892.

297 DPIE (2020) *AdaptNSW*. Available at: https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region.

298 Sanderson, B.M. and Fisher, R.A. (2020) 'A fiery wake-up call for climate scientists'. *Nature Climate Change* 10: 175–177. Available at: https://doi.org/10.1038/s41558-020-0707-2.

299 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

300 Collins, L., Bradstock, R.A., Clarke, H., Clarke, M.F., Nolan, R.H., and Penman, T.D. (2021) 'The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire'. *Environmental Research Letters*, 16: 044029. Available at: https://doi.org/10.1088/1748-9326/abeb9e.

conservation are likely. The capacity of management actions to counter such changes may be limited, given the magnitude of risks.

More broadly, across the forest estate, major interventions, such as targeted defence of refugia and key populations (for example, as carried out for the Wollemi Pine during the Gosper's Mountain Fire in late 2019) may be required along with other actions such as translocations. [301]

Managing changes to fire regimes and associated increased risks to people, property and environmental values (such as those embodied in the Coastal IFOA) is a key challenge. There are many management options, including changes to rapid detection of ignition, suppression and hazard reduction, all of which involve interventions in the landscape. Some of these options were the subject of review and recommendations by the NSW Independent Bushfire Inquiry in 2020.[302] For example, the Inquiry recommended changes to detection and aerial suppression capabilities and an increase in hazard reduction activities that strategically target areas of high ignition probability from lightning and the interface between bushland and development.

There is limited data on the effectiveness of these actions in mitigating the impacts of climate change.[303] However, the Bushfire and Natural Hazards Cooperative Research Centre's Prescribed Burning Atlas provides some information on possible effects of climate change in altering the risk mitigation potential of differing prescribed fire strategies.[304]

Many of the key processes that govern the future dynamics of eucalypt forests under climate change remain incompletely understood, meaning that future scenarios of change in structure and composition remain speculative.[305] Nonetheless, under a hotter and possibly drier future, the risks to forest integrity are likely to increase both directly and indirectly (i.e. through changed fire regimes).[306] Whether or not such changes are incremental or sudden, as wrought by the 2019/20 fire season, there remains a strong likelihood that change will be rapid. [307]

Given the current state of vulnerability of ecosystems and biodiversity within the Coastal IFOA, there is a need to identify and prioritise the most critical ecological elements and their localities, including: [308]

---

301 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

302 NSW Government (2020) *Final Report of the NSW Bushfire Inquiry July 2020.* Available at: https://www.nsw.gov.au/nsw-government/projects-and-initiatives/nsw-bushfire-inquiry.

303 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

304 Bushfire and Natural Hazards Cooperative Research Centre (2020) *The Prescribed Burning Atlas: a new system to plan effective prescribed burns. Hazard Notes December 2020.* Available at: https://www.bnhcrc.com.au/hazardnotes/87.

305 Bowman, D.M.J.S., Williamson, G.J., Price, O.F., Ndalila, M.N. and Bradstock, R.A. (2020) 'Australian forests, megafires and the risk of dwindling carbon stocks'. *Plant, Cell and Environment.* 2020: 1-9.

306 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

307 *Ibid.*

308 *Ibid.*

- known locations of threatened species and habitat features they are dependent on
- endangered ecological communities
- landforms that remain vulnerable to soil and carbon loss
- any of these areas that were unburnt in 2019/20 or burnt and showing strong recovery.

The Commission's pathway approach builds in the best available information to address these priorities, and where existing data or research is lacking, makes recommendations to address these gaps.

This information will not only inform decisions made in relation to the Coastal IFOA, it will also be critical to inform the development of actions or plans to aid in the response to future, large-scale fire events. Importantly, the magnitude of risks cannot be addressed by action on one single land tenure or at one single scale – a multi-scale, multi-tenure approach is needed. The NSW Forest Monitoring and Improvement Program provides an existing platform for cross-agency discussion, planning, research and action for the NSW forest estate across tenures.

7 Understanding the impacts of fire and forestry

The Commission has considered the available scientific evidence on the environmental impacts of forestry operations under the standard Coastal IFOA prescriptions and SSOCs in areas affected by the 2019/20 wildfires.

The intensity of disturbance in terms of the proportion of a compartment and landscape harvested is an important consideration in assessing the cumulative impact of fire and harvesting on biodiversity at these broader scales.[309]

This chapter outlines the evidence on cumulative impacts of post-fire harvesting operations and associated management implications in NSW fire-affected forests. While there is little direct evidence of the impacts of forestry in 2019/20 fire-affected Coastal IFOA areas, other studies in NSW forests, as well as in other Australian and international jurisdictions provide some insights (**Section 7.1**).

While the findings of these studies provide some insights, there are uncertainties in translating their findings directly to the NSW operational context.

The collated information from local, Australian and international studies have informed the Commission's pathway approach at all levels. This includes the precautionary approach adopted at the Gateway 1 risk assessment, capturing impacts across all forested land tenures, down to the subsequent gateway 2 and 3 checks and the additional measures proposed at the operational scale to mitigate the risk of harvesting in a fire-affected landscape. These measures address the cumulative impacts being cognisant of the best practice retention-based framework that underpins the Coastal IFOA.

7.1 Available evidence of cumulative impacts

The comprehensive review of published scientific literature undertaken for this review found that there is little published evidence on the impacts of forestry in 2019/20 fire-affected areas under the Coastal IFOA or SSOCs in NSW.[310] This is not unexpected, as there has been limited time to establish monitoring and research in the aftermath of the wildfires and the Coastal IFOA was only introduced in late 2018.

309 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

310 *Ibid*.

However, there are historical and ongoing studies in NSW forests that have considered fire and forestry impacts, for example:

- some fauna species, including the koala,[311] greater glider,[312] eastern pygmy possum (*Cercartetus nanus*),[313] white-footed dunnart (*Sminthopsis leucopus*)/brown antechinus (*Antechinus stuartii*)/bush rat (*Rattus fuscipes*),[314] various possums/gliders,[315] bats[316] and various lizards[317]
- plant diversity[318, 319, 320]
- flowering patterns[321]
- coarse woody debris[322, 323]
- hollow-bearing trees[324, 325]
- streamflow.[326]

While these studies provide an understanding of some cumulative impacts of fire and forestry, they were not designed or intended to address the landscape and regional scale issues, such as wood supply and various environmental values, created by the unprecedented extent of the 2019/20 fires.

311 Law, B.S. Brassil, T. Gonsalves, L. Roe, P. Truskinger, A. and McConville, A. (2018) 'Passive acoustics and sound recognition provide new insights on status and resilience of an iconic endangered marsupial (koala *Phascolarctos cinereus*) to timber harvesting'. *PLoS One*, 13.

312 McLean, C.M. Bradstock, R. Price, O. and Kavanagh, R.P. (2015) 'Tree hollows and forest stand structure in Australian warm temperate Eucalyptus forests are adversely affected by logging more than wildfire'. *Forest Ecology and Management*, 341: 37–44.

313 Law, B. Chidel, M. Britton, A. and Threlfall, C. (2018) 'Comparison of microhabitat use in young regrowth and unlogged forest by the eastern pygmy-possum (*Cercartetus nanus*)'. *Australian Mammalogy*, 40: 1–9.

314 Lunney, D. and Ashby, E. (1987) 'Population Changes in *Sminthopsis leucopus* (Gray) (Marsupialia : Dasyuridae), and other Small Mammal Species, in Forest Regenerating from Logging and Fire near Bega, New South Wales'. *Australian Wildlife Research*, 14: 275-84.

315 Lunney, D. (1987) 'Effects of Logging, Fire and Drought on Possums and Gliders in the Coastal Forests Near Bega, NSW'. *Australian Wildlife Research*, 14: 263-74.

316 Law, B. (2018) 'Long-term research on forest bats: we have the technology'. *Australian Zoologist* 39(4): 658-668.

317 Lunney, D., Eby, P. and O'connell, M. (1991) 'Effects of logging, fire and drought on three species of lizards in Mumbulla State Forest on the south coast of New South Wales'. *Australian Journal of Ecology*, 16(1): 33-46.

318 Penman, T.D. Binns, D.L. Shiels, R.J. Allen, R.M. and Kavanagh, R.P. (2008) 'Changes in understorey plant species richness following logging and prescribed burning in shrubby dry sclerophyll forests of south-eastern Australia'. *Austral Ecology*, 33: 197–210.

319 Penman, T.D. Binns, and Kavanagh, R.P. (2008) 'Quantifying successional changes in response to forest disturbances'. *Applied Vegetation Science*, 11: 261-268.

320 Penman, T.D. Binns, D.L. Shiels, R.J. Allen, R.M. and Penman, S.H. (2011) 'Hidden effects of forest management practices: responses of a soil stored seed bank to logging and repeated prescribed fire'. *Austral Ecology*, 36: 571-580.

321 Law, B. Mackowski, C. Shoer, L. and Tweedie, T. (2000) 'Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales'. *Austral Ecology*, 25: 160–178.

322 Collins, L., Bradstock, R., Ximenes, F., Horsey, B., Sawyer, R., and Penman, T. (2018) 'Aboveground forest carbon shows different responses to fire frequency in harvested and unharvested forests.' *Ecological Applications*, 29(1).

323 Stares, M.G., Collins, L., Law, B. and French, K. (2018) 'Long-Term Effect of Prescribed Burning Regimes and Logging on Coarse Woody Debris in South-Eastern Australia.' *Forests*, 9, 242.

324 Gibbons P., Lindenmayer D., Barry S. and Tanton M. (2000) 'The effects of slash burning on the mortality and collapse of trees retained on logged sites in south-eastern Australia.' *Forest Ecology and Management* 139, 51-61.

325 Gibbons P., Cunningham R. and Lindenmayer D. (2008) 'What factors influence the collapse of trees retained on logged sites?: A case-control study.' *Forest Ecology and Management* 255, 62-7.

326 Webb, A. A. and Jarrett, B. W. (2013) 'Hydrological response to wildfire, integrated logging and dry mixed species eucalypt forest regeneration: The Yambulla experiment'. *Forest Ecology and Management*, 306:107-117.

To capture this broader range of environmental values, interjurisdictional studies of fire (or other disturbances) and forestry were also considered for this review. These studies largely focus on more intensive harvesting approaches (traditional salvage logging) than those applied in NSW, and the impacts the studies describe may be greater than what could be expected under harvesting under the Coastal IFOA. Additionally, many of these studies focus on different forest types (dominated by obligate seeders, conifers, or plantations) in different landscape contexts.

A common theme that emerged in the review is that impacts on biodiversity, aquatic ecosystems, soil resources, and water quantity and quality are sensitive to the amount of an area disturbed by timber harvesting within catchments and compartments.[327] The intensity of disturbance in terms of the proportion of a compartment and landscape harvested is an important consideration in assessing the cumulative impact of fire and harvesting on biodiversity at these broader scales. Of note, the Coastal IFOA establishes rules that limit harvesting in time and space to disperse the short-term disturbance impacts of forestry operations. For example, only 10 percent of the net harvest area within a management zone can be harvested annually. In addition, intensive harvesting is restricted to no more than 2,200 hectares per year.

The impacts of harvesting on the landscape influence the impact of and recovery from future harvesting.[328] In addition, infrequent, high-intensity disturbances (such as large-scale intense wildfires) can have impacts on forested landscapes, changing forest structure and altering relative species abundance.[329] The cumulative effects of wildfire, pre-fire harvesting and post-fire harvesting in surrounding landscapes must also be considered. This is because recovery rates of common species have been found to be negatively related to the amount of landscape disturbance.[330] The response and recovery of biodiversity will be influenced by the amount and intensity of disturbance at both the compartment and local landscape area scale.[331]

These potential cumulative impacts would be the result of the cumulative loss of ecosystem legacies at finer scales that flow through into broader scale impacts on ecosystem function and processes.[332] Ecosystem legacies are the biological remnants after a disturbance such as fire.[333] They include material legacies such as dead standing trees (i.e. stags), large living trees, stumps, coarse woody debris, undisturbed areas of forest floor, organic matter, residual seeds in

327 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

328 Nitschke, C. (2021) *Critical review of reports by Smith (2020) and Forestry Corporation of NSW (2020)*. University of Melbourne. A report provided to the Commission for this review.

329 Trouvé, R., Oborne. L. and Baker P.J. (2021) 'The effect of species, size, and fire intensity on tree mortality within a catastrophic bushfire complex'. *Ecological Applications*, doi:10.1002/eap.2383.

330 Wardlaw, T.J., Grove, S.J., Hingston, A.B., Balmer, J.M., Forster, L.G., Musk, R.A. and Read, S.M. (2018) 'Responses of flora and fauna in wet eucalypt production forest to the intensity of disturbance in the surrounding landscape'. *Forest ecology and management*, 409: 694-706.

331 *Ibid.*

332 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

333 Jögiste, K., Korjus, H., Stanturf, J. A., Frelich, L. E., Baders, E., Donis, J., Jansons, A., Kangur, A., Köster, K., Laarmann, D., Maaten, T., Marozas, V., Metslaid, M., Nigul, K., Polyachenko, O., Randveer, T. and Vodde, F. (2017) 'Hemiboreal forest: natural disturbances and the importance of ecosystem legacies to management'. *Ecosphere*, 8: e01706.

seedbanks and information legacies such as plant composition and the spatial arrangement of material legacies within forest stands and landscapes.[334]

This means that when planning post-fire harvesting operations, the scale of operations and the retention of unburnt and lightly burnt forest are critical matters to consider.

The Commission notes that harvesting occurs across only a small proportion of forest. Approximately 2 percent of the broader native forest estate within the Coastal IFOA region is harvested in any year.[335] Further, the Coastal IFOA standard prescriptions are retention-based, seeking to protect important environmental values. The 2019/20 wildfires have significantly increased the current and future risks associated with harvesting due to the large extent of the fires and the significant damage to species and the habitat they are dependent on. However, careful management to retain key ecosystem legacies and restrict the scale of further disturbance (i.e. forestry operations) in the more severely fire-affected landscapes will mitigate these risks.

The following sections summarise the evidence on the impacts and characteristics of wildfire and the potential cumulative impacts of post-fire harvesting operations and outline associated management implications for proposed retention-based salvage logging in NSW fire-affected forests.

Fire extent and severity are not homogenous

Wildfires create a mosaic of unburnt, lightly burnt and more severely burnt forest across the landscape with impacts varying at different scales.[336] These unburnt and lightly burnt areas are ecosystem legacies, important biological legacies left after the fires.[337] Ecosystem legacies in the unburnt and lightly burnt forest, such as nectar resources or habitat trees, are important to support the persistence of fauna species as the forests recover post-fire. In addition, the unburnt and lightly burnt forest may provide seeds that can disperse into adjacent burnt areas.

Protecting unburnt and lightly burnt areas when planning or conducting post-fire harvesting operations is critical. Therefore, a degree of flexibility in retention measures is required to enable targeting of unburnt and lightly burnt areas for retention at the site scale (i.e. within compartments and local landscape areas).

334 *Ibid.*

335 Forestry Corporation of NSW (2020) *2019-20 Wildfires – Environmental impacts and implications for timber harvesting in NSW state forests. An assessment of the impact of the 2019-20 fire season on biodiversity, soil and water values and implications for managing ongoing timber harvesting operations in native State forests.*

336 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

337 Jögiste, K., Korjus, H., Stanturf, J. A., Frelich, L. E., Baders, E., Donis, J., Jansons, A., Kangur, A., Köster, K., Laarmann, D., Maaten, T., Marozas, V., Metslaid, M., Nigul, K., Polyachenko, O., Randveer, T. and Vodde, F. (2017) 'Hemiboreal forest: natural disturbances and the importance of ecosystem legacies to management'. *Ecosphere*, 8: e01706.

Harvesting in a disturbed landscape may impact forest structure and ecosystem legacies

Harvesting in a disturbed landscape can result in the simplification and homogenisation of forest structure and loss of ecosystem legacies that are required for maintaining biodiversity and ecological functioning.[338, 339] The location, scale, and intensity of post-disturbance harvesting are important to consider in determining the negative impacts associated with salvage harvesting on biodiversity and ecosystem services and functioning. [340, 341, 342, 343] Studies on traditional salvage harvesting impacts in Australian forests on plant communities,[344] on bird communities[345] and on forest soils,[346] support these patterns. However, these studies were focused on salvage logging where clearfelling was used to salvage timber for economic gain. Clearfelling is not practiced in NSW native state forest.

A meta-data analysis (i.e. an overarching study of the results of other scientific studies) using international and Australian salvage logging (clearfell) studies shows that the amount of post-disturbance harvesting influences an area's unique biodiversity. For example, this study found that retaining more than 75 percent of post-disturbance area can maintain 90 percent of an area's unique biodiversity. Retaining 50 percent of the post-disturbance area can maintain 73 percent of an area's unique biodiversity.[347] The transferability of salvage harvesting studies to the NSW retention based harvesting approach is unclear, but as a general principle the amount of harvesting following disturbance is important to consider.

338 Leverkus, A. B., Gustafsson, L. Lindenmayer, D. B. Castro, J. Rey Benayas, J. M. Ranius, T. and Thorn, S. (2020) 'Salvage logging effects on regulating ecosystem services and fuel loads.' *Frontiers in Ecology and the Environment*, 18: 391-400.

339 Leverkus, A.B. Buma, B. Wagenbrenner ,J. Burton, P.J. Lingua, E. Marzano, R. and Thorn, S. (2021) 'Tamm review: Does salvage logging mitigate subsequent forest disturbances?'. *Forest Ecology and Management*, 481: 118721.

340 Leverkus, A. B., Gustafsson, L. Lindenmayer, D. B. Castro, J. Rey Benayas, J. M. Ranius, T. and Thorn, S. (2020) 'Salvage logging effects on regulating ecosystem services and fuel loads.' *Frontiers in Ecology and the Environment*, 18: 391-400.

341 Leverkus, A.B. Buma, B. Wagenbrenner ,J. Burton, P.J. Lingua, E. Marzano, R. and Thorn, S. (2021) 'Tamm review: Does salvage logging mitigate subsequent forest disturbances?'. *Forest Ecology and Management*, 481: 118721.

342 Thorn, S. Bässler, C. Brandl, R. Burton, P. J. Cahall, R. Campbell, J. L. Castor, J. Choi, C.-Y. Cobb, Donato, D. C. Durska, E. Foantaine, J.B. Gauthier, S. Hebert, C. Hothorn, T. Hutto, R.L. Lee, E-J. Leverkus, A.B, Lindenmayer, D.B. Obrist, M.K. Rost, J. Seibold, S, Seidl, R. Thom, D. Waldron, K. Wermelinger, B. Winter, M.-B. Zmihorski, M. and Müller, J. (2018) 'Impacts of salvage logging on biodiversity: A meta-analysis'. *Journal of Applied Ecology*, 55: 279-289.

343 Thorn, S. Chao, A. Georgiev ,K.B. Müller, J. Bässler, C. Campbell J.L. Castor, J. Chen, Y.-H. Choi, C.-Y. Cobb, T.P. Donato, D.C. Durska, E. Macdonald, E. Feldhaar, H. Fontaine, J.B. Fornwalt, P.J. Hernández, R.M.H. Hutto, R.L. Koivula, M. Lee, E.-J. Lindenmayer, D. Mikusiński, G. Obrist, M.K. Perlik,M. Rost, J. Waldron, K. Wermelinger, B. Weiß, I. Zmihorski, M. and Leverkus, A.B. (2020) 'Estimating retention benchmarks for salvage logging to protect biodiversity'. *Nature Communications*, 11: 4762.

344 Blair, D.P., McBurney, L.M., Blanchard, W., Banks, S.C. and Lindenmayer, D.B. (2016) 'Disturbance gradient shows logging affects plant functional groups more than fire'. *Ecological Applications*, 26: 2280-2301.

345 Lindenmayer, D.B., McBurney, L., Blair, D., Wood, J. and Banks, S.C. (2018) 'From unburnt to salvage logged: Quantifying bird responses to different levels of disturbance severity'. *Journal of Applied Ecology*, 55: 1626-1636.

346 Bowd, E.J. Lindenmayer, D.B. Banks, S.C. and Blair, D.P. (2018) 'Logging and fire regimes alter plant communities. *Ecological Applications*', 28(3): 826-841.

347 Thorn, S. Chao, A. Georgiev ,K.B. Müller, J. Bässler, C. Campbell J.L. Castor, J. Chen, Y.-H. Choi, C.-Y. Cobb, T.P. Donato, D.C. Durska, E. Macdonald, E. Feldhaar, H. Fontaine, J.B. Fornwalt, P.J. Hernández, R.M.H. Hutto, R.L. Koivula, M. Lee, E.-J. Lindenmayer, D. Mikusiński, G. Obrist, M.K. Perlik,M. Rost, J. Waldron, K. Wermelinger, B. Weiß, I. Zmihorski, M. and Leverkus, A.B. (2020) 'Estimating retention benchmarks for salvage logging to protect biodiversity.' *Nature Communications*, 11: 4762.

Harvesting in a disturbed landscape can negatively affect some species and positively affect others.[348] Therefore it is important to understand the regeneration response of vegetation post disturbance and the habitat requirements of species.[349]

The multi-scale site and landscape protections under the Coastal IFOA, coupled with the reserve system across the forest estate, were designed to protect native flora and fauna and provide for their persistence. If the wildfires have compromised the ecological structure and function of these areas, then unburnt and lightly burnt forest elsewhere in the state forest estate may be needed as a temporary refuge while species recover and recolonise more severely burnt areas.

The level of impact across the forest estate and within the reserve system are important considerations when understanding the cumulative impact that an additional disturbance (i.e. post-fire harvesting) may have on forest dependent species. By providing temporary refuges in state forest that are targeted at protecting ecosystem legacies as the forest recovers, the cumulative impacts of forestry operations will likely be kept within acceptable risk levels. In some areas this may mean avoiding or significantly restricting harvesting operations until a suitable level of recovery has occurred.

Loss of habitat and feed resources

Following a disturbance, the response and recovery of biodiversity is influenced by the amount, intensity, and recurrence of disturbance at both the compartment and local landscape-scales. This is a result of the cumulative loss and rearrangement of ecosystem legacies at finer scales and how they relate to broader scale impacts on ecosystem function and processes. The retention of ecosystem legacies in terms of types, amounts and spatial arrangement at the compartment-scale are important components for maintaining biodiversity in disturbed areas but also for facilitating recovery.[350]

Severe and extensive wildfire depletes available food resources (including foliage, nectar and fruits) and habitat resources (including hollow-bearing trees and coarse woody debris). Studies of traditional salvage logging operations have shown that logging in disturbed forests can further deplete these resources, with higher intensity logging having greater impact.[351, 352, 353]

---

348 Thorn, S. Bässler, C. Brandl, R. Burton, P. J. Cahall, R. Campbell, J. L. Castor, J. Choi, C.-Y. Cobb, Donato, D. C. Durska, E. Foantaine, J.B. Gauthier, S. Hebert, C. Hothorn, T. Hutto, R.L. Lee, E-J. Leverkus, A.B, Lindenmayer, D.B. Obrist, M.K. Rost, J. Seibold, S, Seidl, R. Thom, D. Waldron, K. Wermelinger, B. Winter, M.-B. Zmihorski, M. and Müller, J. (2018) 'Impacts of salvage logging on biodiversity: A meta-analysis'. *Journal of Applied Ecology*, 55: 279-289.

349 Analysis presented in Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

350 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

351 Wardlaw, T.J. Grove, S.J. Hingston, A.B. Balmer, J.M. Forster, L.G. Musk, R.A. and Read, S.M. (2018) 'Responses of flora and fauna in wet eucalypt production forest to the intensity of disturbance in the surrounding landscape'. *Forest ecology and management*, 409: 694-706.

352 Thorn, S. Bässler, C. Bernhardt-Römermann, M. Cadotte, M. Heibl, C. Schäfer, H. Seibold, S. and Müller, J. (2016) 'Changes in the dominant assembly mechanism drive species loss caused by declining resources'. *Ecology Letters*, 19: 163-170.

353 Thorn, S. Bässler, C. Brandl, R. Burton, P. J. Cahall, R. Campbell, J. L. Castor, J. Choi, C.-Y. Cobb, Donato, D. C. Durska, E. Foantaine, J.B. Gauthier, S. Hebert, C. Hothorn, T. Hutto, R.L. Lee, E-J. Leverkus, A.B, Lindenmayer, D.B. Obrist, M.K. Rost, J. Seibold, S, Seidl, R. Thom, D. Waldron, K. Wermelinger, B. Winter, M.-B. Zmihorski, M. and Müller, J. (2018) 'Impacts of salvage logging on biodiversity: A meta-analysis. *Journal of Applied Ecology*', 55: 279-289.

Translating this to the NSW context, the risk is that harvesting operations in severely fire-affected landscapes may further reduce available feed and habitat resources at a site-scale if these operations are not appropriately planned and managed.

As the impacts of fire can be highly variable even at the site scale, this means it is important to carefully plan post-fire harvesting operations to ensure sufficient feed and habitat resources remain in the landscape (for example, inside or outside existing exclusions) to support the recolonisation and persistence of the species that depend on them. This is one area where some NSW-specific studies exist. Where species-specific information (flora and fauna) exist, this data should be considered when planning harvesting operations in areas where these species are found. Some examples include:

- There is evidence that the mortality and collapse of trees retained in logged sites increases with logging intensity and the severity of post-logging fire.[354, 355] Species dependent on hollow-bearing trees (such as gliders) require the retention of existing hollow-bearing trees at rates that meet the requirements of the species,[356] as well as the permanent retention of approximately two to three recruitment trees (for example, potential future hollow-bearing trees) for each hollow-bearing tree to perpetuate the hollow resource.[357]
- The flowering patterns of 20 tree species on the mid-north coast were studied over a decade including the effects of climate, harvesting and fire. Key findings include that under low to moderate fire severity, eucalypts and the understorey vegetation often recover rapidly through the production of epicormic foliage and sometimes blossom. This spike in fresh growth is favoured by many fauna species. Fire can stimulate flowering in some understorey species. Low intensity burns and wildfires caused differing amounts of crown scorch, sometimes resulting in bud loss, but most species considered in the study flowered at pre-fire levels one to three years after the disturbance.[358]
- The cumulative effects of planned fire and selective logging was found to increase large tree mortality in the Eden region.[359] The study's findings suggest increased mortality of large trees may occur in areas of forest selectively logged prior to the 2019/20 wildfires, even in areas that experienced lower fire severity.[360]

354 Gibbons P., Lindenmayer D., Barry S. and Tanton M. (2000) 'The effects of slash burning on the mortality and collapse of trees retained on logged sites in south-eastern Australia.' *Forest Ecology and Management* 139, 51-61.

355 Gibbons P., Cunningham R. and Lindenmayer D. (2008) 'What factors influence the collapse of trees retained on logged sites?: A case-control study'. *Forest Ecology and Management* 255: 62-7.

356 As summarised in Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

357 Gibbons, P., McElhinney, C. and Lindenmayer, D.B. (2010) 'What strategies are effective for perpetuating structures provided by old trees in harvested forests? A case study on trees with hollows in south-eastern Australia'. *Forest Ecology and Management*, 260: 975–982.

358 Law, B. Mackowski, C. Shoer, L. and Tweedie, T. (2000) 'Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales'. *Austral Ecology*, 25: 160–178.

359 Watson, G.M. French, K. and Collins, L. (2020) 'Timber harvest and frequent prescribed burning interact to affect the demography of Eucalypt species'. *Forest Ecology and Management*, 475: 118463.

360 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

- While traditional salvage harvesting results in lower levels of coarse woody debris,[361,362] selectively harvested forests in NSW have been found to have twice the coarse woody debris as unharvested sites.[363] Harvest practices post-fire that result in a similar level and dispersion of coarse woody debris as was present pre-harvest[364] are not likely to impact coarse woody debris-dependent species compared to harvesting in unburnt forests.[365]
- Retained browse and feed trees are important ecosystem legacies within harvested compartments for koalas, which allows them to use both harvested and unharvested areas as habitat.[366]

Based on the literature or critical reviews, the expert reviewers[367, 368] suggested:

- wildfire refugia should be considered for protection if there is limited amount of these areas on post-fire landscape and if they contain foraging and habitat trees for fauna and or an intact understorey
- post-fire harvesting, following Coastal IFOA practices, should result in no net loss of sap or food trees between areas subjected to post-fire harvesting compared to harvesting conducted prior to the 2019/20 wildfires
- the retention of tree patches within compartments benefits biodiversity at fine scales. Increasing minimum patch sizes to 0.5 hectares could be considered after identifying the needs of species likely to be present – along with research around size, amount, spatial dispersion and location of patches within compartments for different fauna. Note, the current Coastal IFOA condition for tree retention clumps is for a minimum size of 0.1 hectares. However wildlife habitat clumps already have a minimum size requirement of 1 hectare.

361 Thorn, S. Bässler, C. Bernhardt-Römermann, M. Cadotte, M. Heibl, C. Schäfer, H. Seibold, S. and Müller, J. (2016) 'Changes in the dominant assembly mechanism drive species loss caused by declining resources'. *Ecology Letters*, 19: 163-170.

362 Thorn, S. Bässler, C. Brandl, R. Burton, P. J. Cahall, R. Campbell, J. L. Castor, J. Choi, C.-Y. Cobb, Donato, D. C. Durska, E. Foantaine, J.B. Gauthier, S. Hebert, C. Hothorn, T. Hutto, R.L. Lee, E-J. Leverkus, A.B, Lindenmayer, D.B. Obrist, M.K. Rost, J. Seibold, S, Seidl, R. Thom, D. Waldron, K. Wermelinger, B. Winter, M.-B. Zmihorski, M. and Müller, J. (2018) 'Impacts of salvage logging on biodiversity: A meta-analysis'. *Journal of Applied Ecology*, 55: 279-289.

363 Threlfall, C.G. Law, B.S. and Peacock, R.J. (2019) 'Benchmarks and predictors of coarse woody debris in native forests of eastern Australia'. *Austral Ecology*, 44: 138–150.

364 Law, B., Brassil, T. and Gonsalves, L. (2016) 'Recent decline of an endangered, endemic rodent: does exclusion of disturbance play a role for Hastings River mouse (*Pseudomys oralis*)?' *Wildlife Research*, 43: 482-491.

365 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

366 Law, B.S. Brassil, T. Gonsalves, L. Roe, P. Truskinger, A. and McConville, A. (2018) 'Passive acoustics and sound recognition provide new insights on status and resilience of an iconic endangered marsupial (koala *Phascolarctos cinereus*) to timber harvesting'. *PLoS One*, 13.

367 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

368 Nitschke, C. (2021) *Critical Review of Reports by Smith (2020) and Forestry Corporation of NSW (2020)*. University of Melbourne. A report provided to the Commission for this review.

Hollow-bearing trees need careful management to persist in the long-term

Fire can act as an agent of hollow loss and creation,[369, 370] and the number of hollow-bearing trees has been found to decline with fire frequency.[371] Fire can also accelerate the formation of hollows through the creation of dead trees.[372, 373] Harvesting has the potential to exacerbate the effects of fire on the loss of hollow-bearing trees. Although not studied extensively, there is evidence that trees retained on logged sites have higher rates of mortality and collapse than trees in comparable unlogged sites[374] and the mortality and collapse of trees retained in logged sites increases with logging intensity and the severity of post-logging fire.[375]

To be effective, the retention of hollow-bearing trees and recruitment trees must be permanent. However, the Commission was asked to determine where, when and how it is practicable to commence forestry operations under standard conditions, which by implication precludes recommending additional measures that would create permanent retentions.

The Commission acknowledges that the Coastal IFOA standard prescriptions already require the permanent retention of eight hollow-bearing trees per hectare where they exist. Advice received from the EPA and FCNSW during this review indicates that in some forests hollow-bearing trees do not exist at this rate and the resource may be limited or non-existent. Our review also suggests that after the extensive and severe fires the hollow-bearing tree resource is at risk of loss.

While the Commission has not been asked to review existing prescriptions, we have been asked to recommend, using best available evidence, best practice approaches to manage forestry operations in fire-affected forests. Available literature and work currently in progress under the Coastal IFOA monitoring program suggest that the existing prescriptions may not be adequate to maintain the hollow resource in the long-term following the 2019/20 wildfires. The Commission has proposed temporary additional measures relating to hollow-bearing trees and recruitment trees for medium and high-risk zones. However, the Commission considers the following measures could also enhance the standard Coastal IFOA prescriptions:

- retain a minimum of eight hollow-bearing trees per hectare where they exist (as per the requirement in the standard Coastal IFOA prescriptions)
- if hollow-bearing trees are not available, then retain suitable substitutes, in priority order being, potential future hollow-bearing trees, the largest mature tree in the stand or a regrowth tree that is not suppressed

369 Inions G. B., Tanton M. T. and Davey S. M. (1989) 'Effects of fire on the availability of hollows in trees used by the Common Brushtail Possum, *Trichosurus vulpecula Kerr*, 1792, and the Ringtail Possum, *Pseudocheirus peregrinus Boddaerts*, 1785'. *Australian Wildlife Research,* 16: 449-58.

370 Salmona J., Dixon K.M. and Banks S.C. (2018) 'The effects of fire history on hollow-bearing tree abundance in montane and subalpine eucalypt forests in southeastern Australia'. *Forest Ecology and Management* 428: 93-103.

371 *Ibid.*

372 Adkins M.F. (2006) 'A burning issue: using fire to accelerate tree hollow formation in Eucalyptus species'. *Australian Forestry*, 69: 107-13.

373 Salmona J., Dixon K.M. and Banks S.C. (2018) 'The effects of fire history on hollow-bearing tree abundance in montane and subalpine eucalypt forests in southeastern Australia'. *Forest Ecology and Management* 428: 93-103.

374 Koch, A.J., Chuter, A. Barmuta, L. A. Turner, P. and Munks, S. A. (2018) 'Long-term survival of trees retained for hollow-using fauna in partially harvested forest in Tasmania, Australia.' *Forest Ecology and Management*, 422: 263-272.

375 Gibbons P., Lindenmayer D., Barry S. and Tanton M. (2000) 'The effects of slash burning on the mortality and collapse of trees retained on logged sites in south-eastern Australia'. *Forest Ecology and Management,* 139: 51-61.

- retain two recruitment trees per retained hollow-bearing tree[376]
- adopt the FCNSW guidance material for hollow-bearing trees[377] with expanded content to cover recruitment and substitute hollow-bearing trees and other forest types if relevant[378] or other suitable guidance developed in conjunction with FCNSW[379]
- recruitment trees can be retained in clumps
- hollow recruitment trees should be recorded and retained if they are outside of clumps
- at subsequent logging events these trees should be retained or replaced if they are no longer present.

The Commission suggest this information be considered under the Coastal IFOA monitoring program and acknowledges that work is already underway regarding the effectiveness of the retained hollow-bearing tree measures. Ahead of this matter being considered under Coastal IFOA review processes, the proposed additional temporary measures for hollow-bearing trees in medium and high-risk zones should be implemented for a period of 10 years. By this time, the Coastal IFOA processes should have been conducted and resolved with relevant stakeholders. After the conclusion of this process the retained trees under the additional measures could either be permanently retained or no longer retained, in accordance with the outcomes of the Coastal IFOA review process.

Vulnerability of species to fire and multiple disturbances

Based on the literature collated for this review, the response of fauna to disturbance, including fire and forestry, varies significantly amongst species and in relation to the intensity and severity of the disturbance. In addition, species responses vary by scale, meaning a negative response observed at the site scale may not be observed at the landscape scale. Some species respond positively to disturbance, while others do not. Studies conducted in NSW forests and in forests in other Australian jurisdictions have considered some key fauna species and the impacts of forestry in unburnt forests, or the impacts of fire. There are limited studies that have considered both fire and forestry.

Some examples of how different forest fauna species respond to disturbance at various scales, include:

- the mosaic of harvested and unharvested forests at the compartment scale (around 200 to 250 hectares) created by exclusion areas and habitat protection for owls has been identified as a reason for koalas to persist in compartments where around 50 percent of the area was harvested[380]

376 Gibbons, P., McElhinney, C. and Lindenmayer, D.B. (2010) 'What strategies are effective for perpetuating structures provided by old trees in harvested forests? A case study on trees with hollows in south-eastern Australia'. *Forest Ecology and Management*, 260: 975–982.

377 Forestry Corporation of NSW (2021) *Tree retention guidance South Coast and Eden, Coastal IFOA Implementation.*

378 Personal communication, Professor Philip Gibbons, The Australian National University. In advice requested by the Commission for this review.

379 The EPA advised that it is preparing guidance material for hollow-bearing tree identification and this will soon be published. The Commission has not seen this guidance material.

380 Law, B.S. Brassil, T. Gonsalves, L. Roe, P. Truskinger, A. and McConville, A. (2018) 'Passive acoustics and sound recognition provide new insights on status and resilience of an iconic endangered marsupial (koala *Phascolarctos cinereus*) to timber harvesting'. *PLoS One*, 13.

- at broader spatial scales (greater than 700 hectares) forest owls, bats, nightjars and marsupial gliders and possums had no significant relationship with harvesting[381]
- while greater glider and sugar glider (*Petaurus breviceps*) were negatively affected by harvesting at the compartment or coupe scale (45 to 250 hectares), within a mosaic of harvested and unharvested forests at broader spatial scales, there was no detectable impact, while koalas and yellow-bellied gliders showed no significant response to harvesting at the compartment scale[382]
- the occurrence of Hastings River mouse in harvested sites is significantly related to the occurrence of coarse woody debris, with species abundance higher in areas logged 2 to 15 years ago compared to unlogged areas – researchers suggests that disturbance is likely to influence their persistence[383]
- dense regrowth in regenerating forest that had been subject to historic clearfell operations and fire may negatively impact echolocating bats, but retention-based harvesting history had little effect (either no effect, or minor positive and negative effects) on bat survival and no effect on abundance or body condition – environmental protection measures (and tracks) appeared to mitigate the impacts of dense regrowth and bats likely used these features at a local landscape scale[384]
- the long-nose potoroo was found able to persist in disturbed areas where habitat complexity was high[385, 386] while small mammals were found able to persist in retention patches and move through regenerating forests as habitat cover recovered.[387] This suggests that fine-scale heterogeneity within coupes and compartments are important for persistence post-disturbance[388]
- the agile antechinus (*Antechinus agilis*) and bush rat were unaffected by timber harvesting at the compartment scale, but the southern forest cool-skink (*Carinascincus coventryi*) and the eastern banjo frog (*Limnodynastes dumerilii*) were negatively impacted by harvesting at the compartment scale.[389]

The multi-scaled response of species to habitat provision can be challenging to manage. An understanding of species requirements combined with spatial analysis is needed to determine the appropriate level of retention at site and landscape scales for planning fire-affected forestry

381 Kavanagh, R.P. and Bamkin, K.L. (1995) 'Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in south-eastern New South Wales, Australia'. *Biological Conservation*, 71: 41-53.

382 *Ibid*.

383 Law, B. Brassil, T. and Gonsalves, L. (2016) 'Recent decline of an endangered, endemic rodent: does exclusion of disturbance play a role for Hastings River mouse (*Pseudomys oralis*)?' *Wildlife Research*, 43: 482-491.

384 Law, B. (2018) 'Long-term research on forest bats: we have the technology'. *Australian Zoologist* 39(4): 658-668.

385 Catling, P.C. Coops, N.C. and Burt, R.J. (2001) 'The distribution and abundance of ground-dwelling mammals in relation to time since wildfire and vegetation structure in south-eastern Australia'. *Wildlife Research*, 28: 555–564.

386 Flynn, E.M. Jones, S.M. Jones, M.E. Jordan, G.J. and Munks, S.A. (2011) 'Characteristics of mammal communities in Tasmanian forests: exploring the influence of forest type and disturbance history'. *Wildlife Research*, 38: 13-29.

387 Stephens, H.C., Baker, S.C., Potts, B.M., Munks, S.A., Stephens, D. and O'Reilly-Wapstra, J.M. (2012) 'Short-term responses of native rodents to aggregated retention in old growth wet Eucalyptus forests.' *Forest Ecology and Management*, 267: 18-27.

388 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

389 Kavanagh, R.P. and Webb, G.A. (1998) 'Effects of variable-intensity logging on mammals, reptiles and amphibians at Waratah Creek, southeastern New South Wales'. *Pacific Conservation Biology*, 4: 326-47.

operations.[390] The Commission's pathway approach builds on the multi-scale, retention-based framework established under the Coastal IFOA. The additional measures applied in medium and high risk managements zones require a spatial analysis of local landscape area to determine where the least impacted habitat (i.e. unburnt and lightly burnt forest) is and to ensure that it is placed in temporary refuges that protect these resources for the species dependent on them as the forest recovers. Further, strong links to the Coastal IFOA monitoring program have been embedded in the reassessment process that will, over time, provide valuable data on species occupancy and forest regeneration after the fires.

Increased erosion risk and impacts on water quality and habitat

Fire-affected landscapes are susceptible to erosion and streamflow variation,[391] which can have implications for aquatic environments.[392] These issues can be worsened in fire-affected catchments that have subsequently been harvested.[393] Wildfires or harvesting operations can lead to lower infiltration capacity and higher surface water runoff and promote erosion through both wind and water.[394]

A key aspect of erosion in post-fire and harvesting environments is extreme rainfall events.[395] Both fire and harvesting remove or reduce groundcover and canopy cover, leaving soils more exposed to rainfall and erosion risk before vegetation groundcover can return. Reduced vegetated groundcover results in less soil stability as the root system is no longer holding the soil together. Rainfall occurring after fire and/or harvesting can exacerbate soil runoff, erosion, vegetation response and loss of soil nutrients.[396] The movement of sediment can be enhanced by the water repellence of soils,[397] which may increase following fires.

Increased sedimentation that occurs following fire or harvesting has been found in various studies to increase in the year following the event but to then reduce to pre-disturbance levels

390 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

391 DeLong, S.B., Youberg, A.M., DeLong, W.M. and Murphy, B.P. (2018) 'Post-wildfire landscape change and erosional processes from repeat terrestrial lidar in a steep headwater catchment, Chiricahua Mountains, Arizona, USA'. *Geomorphology*, 300: 13-30.

392 Emelko, M.B., Stone, M., Silins, U., Allin, D., Collins, A.L., Williams, C.H.S., Martens, A.M. and Bladon, K.D. (2016) 'Sediment-phosphorus dynamics can shift aquatic ecology and cause downstream legacy effects after wildfire in large river systems'. *Global Change Biology*, 22: 3.

393 McIver, J.D. and Starr, L. (2000) Environmental effects of postfire logging: literature review and annotated bibliography, p. 72. General Technical Report, Pacific Northwest Research Station: US Department of Agriculture, Forest Service. Available at: https://www.fs.usda.gov/treesearch/pubs/2955.

394 Inbar, A., Nyman, P., Lane, P.N.J. and Sheridan, G.J. (2020) 'The Role of Fire in the Coevolution of Soils and Temperate Forests'. *Water Resources Research*, 56, e2019WR026005.

395 Nyman, P., Sheridan, G.J., Smith, H.G. and Lane, P.N.J. (2011) 'Evidence of debris flow occurrence after wildfire in upland catchments of south-east Australia'. *Geomorphology*, 125: 383–401; Nyman, P. and Sheridan, G. J. (2014) *Erosion in burned catchments of Australia: Regional synthesis and guidelines for evaluating risk*. Available at: https://www.aidr.org.au/media/7694/nyman-and-sheridan-2015_erosion-in-burned-catchments_afac.pdf.

396 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

397 Blake, W.H., Wallbrink, P.J., Wilkinson, S.N., Humphreys, G.S., Doerr, S.H., Shakesby, R.A. and Tomkins, K.M. (2009) 'Deriving hillslope sediment budgets in wildfire-affected forests using fallout radionuclide tracers'. *Geomorphology*. 104: 105-116.

within two to five years.[398, 399, 400, 401] Variations in time relate to different sites, topography, recovery rates of vegetation, forest type and many other factors. The 2019/20 wildfires happened more than 12 months ago and with the significant rainfall post fires there is now well-established vegetated groundcover in many fire-affected forests.

As with wildfire, the amount of sedimentation in streams increases with the amount of a catchment area that has been harvested.[402] Roads and snig tracks are the dominant sources of sediment in harvested areas.[403] These features can extend existing drainage lines and flow channels, further increasing hydrological connectivity and erosion capacity in impacted sites.[404]

Choosing an appropriate management option to mitigate the impacts of erosion will depend on ecosystem factors, with wetter, more productive sites likely to recover vegetation cover faster than drier, less productive sites.[405]

As noted earlier, there are limited NSW-specific studies in this area. Research is required to understand what management practices are appropriate for water quality and erosion protection and to identify which soils are prone to post-fire increases in runoff and erosion to help target protections.

Without knowledge of where vulnerable post-fire soils are, there is limited data to target restrictions and mitigation actions. As such, key areas for management may be missed, while unnecessary and costly restrictions could be applied in areas where they are not required.

While post-fire forestry operations may increase the risk of erosion, it is important to understand the relative contribution of harvesting in a fire-affected landscape compared to the contributions from the fire-affected landscape. Sedimentation is significantly and positively related to the proportion of a catchment burnt.[406] The Commission's expert panel suggest that in a catchment that has been extensively burnt, the increased risk of erosion and sediment

398 Croke, J., Hairsine, P. and Fogarty, P. (1999) 'Runoff generation and re-distribution in logged eucalyptus forests, south-eastern Australia'. *Journal of Hydrology*, 216: 56-77.

399 Lane, P.N.J., Sheridan, G.J. and Noske, P.J. (2006) 'Changes in sediment loads and discharge from small mountain catchments following wildfire in south eastern Australia'. *Journal of Hydrology*, 331:495–510.

400 Sheridan, G.J., Lane, P.N.J. and Noske, P.J. (2007) 'Quantification of hillslope runoff and erosion processes before and after wildfire in a wet Eucalyptus forest'. *Journal of Hydrology*, 343:12– 28.

401 Smith, H.G., Sheridan, G.J., Lane, P.N.J. and Bren, L.J. (2011) 'Wildfire and salvage harvesting effects on runoff generation and sediment exports from radiata pine and eucalypt forest catchments, south-eastern Australia'. *Forest Ecology and Management*, 261: 570-581.

402 Davies, P., Cook, L., Mallick, S. and Munks, S. (2016) 'Relating upstream forest management to stream ecosystem condition in middle catchment reaches in Tasmania'. *Forest Ecology and Management*, 362: 142-155.

403 Croke, J. Hairsine, P. and Fogarty, P. (1999) 'Sediment transport, redistribution and storage on logged forest hillslopes in south-eastern Australia'. *Hydrological Processes*, 13: 2705-2720.

404 Smith, H. G. Sheridan, G. J. Lane, P. N. J. and Bren, L. J. (2011) 'Wildfire and salvage harvesting effects on runoff generation and sediment exports from radiata pine and eucalypt forest catchments, south-eastern Australia'. *Forest Ecology and Management*, 261: 570-581; Smith, H. G. Hopmans, P. Sheridan, G. J. Lane, P. N. J. Noske, P. J. and Bren, L. J. (2012) 'Impacts of wildfire and salvage harvesting on water quality and nutrient exports from radiata pine and eucalypt forest catchments in south-eastern Australia'. *Forest Ecology and Management*, 263: 160-169.

405 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

406 Wilkinson, S.N., Wallbrink, P.J., Hancock, G., Blake, W., Shakesby, R. and Doerr, S. (2007) *Impacts on Water Quality by Sediments and Nutrients Released During Extreme Bushfires: Report 4: Impacts on Lake Burragorang*, CSIRO Land and Water Science Report for the Sydney Catchment Authority. Available at: https://publications.csiro.au/rpr/download?pid=procite:be24bf38-b8b2-486d-a697-315f78991b11&dsid=DS1.

mobilisation to waterways from properly managed forestry operations will be relatively small compared to the overall impact of the fire to the catchment.

In terms of recovery after wildfire, groundcover plays many roles in reducing erosion:[407]

- reducing raindrop-impact induced erosion by protecting the soil surface from raindrop impact
- mechanically holding the soil in place against rill (concentrated flow) erosion (via roots in the case of vegetation)
- increasing the hydraulic roughness of the surface, reducing the velocity of the overland flow, and thereby reducing detachment of soil from the soil matrix, and increasing sediment deposition trapping behind roughness elements
- preventing surface sealing and crusting of the soil, increasing infiltration and decreasing runoff and erosion
- increasing infiltration via soil aggregate stability and macro-porosity due to plant roots and soil organic matter.

While groundcover can be described as anything other than bare soil (for example, rocks, leaves, twigs, vegetation), not all cover is equally effective as an erosion control - low growing vegetation is much more effective at reducing surface runoff and soil erosion than leaf litter cover.[408]

The Commission has addressed the increased erosion and sedimentation risks in burnt areas through suspending harvesting in extreme risk management zones, or limiting the extent of harvesting operations in areas that are more severely impacted (i.e. in medium and high risk management zones) and also requiring an on-ground assessment of riparian buffer vegetated groundcover recovery. If the recovery threshold is not met than harvesting is not allowed.

Regeneration of forests and potential change in forest structure

Forest disturbance by wildfire is a natural process that shapes forest dynamics.[409] A common management response to wildfire in timber production forests is to harvest timber in disturbed forest where some of the economic value can be recovered. It is commonly referred to as salvage logging.

Globally, post-fire harvesting has been found to have both positive and negative impacts on forest regeneration.[410] Again, studies generally relate to traditional salvage logging operations and species that do not occur in the Coastal IFOA region. However, they provide an indication of possible cumulative impacts and the importance of considering the regeneration and growing needs of the forest species.

407 Written advice from Professor Gary Sheridan, University of Melbourne, provided to the Commission for this review.

408 *Ibid.*

409 Seidl, R., Schelhaas, M.-J., Rammer, W. & Verkerk, P. J. (2014) 'Increasing forest disturbances in Europe and their impact on carbon storage'. *Nature Climate Change*, 4: 806-810.

410 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

Traditional salvage logging[411] focusses on recovering merchantable timber before it degrades following disturbances such as windstorms, insect attack and wildfires[412] and removes most or all of the trees within the harvestable area of a coupe or compartment (i.e. clearfelling). In Australia, salvage logging is usually practised in forest types that are dominated by obligate seeder species,[413] which exhibit significant mortality following wildfire, such as mountain ash (*E. regnans*), alpine ash, or in plantations. While traditional salvage logging is not practiced in the mixed forests of NSW, the term 'salvage logging' is now commonly used to refer to any form of harvesting (thinning, selective, intensive or clearfell) in forest areas affected by natural disturbance.[414]

Most of the forests in NSW affected by the 2019/20 wildfires are dominated by resprouting species rather than obligate seeders. They typically contain mixed stands of eucalyptus/ corymbia/angophora species that regenerate following fire with basal or epicormic resprouting and can continue to live and recover after wildfire events.

The positive and negative impacts of post-fire harvesting reported in international literature include higher regeneration densities,[415, 416] higher seedling survival,[417] lower densities of seedling regeneration[418] and reduced seedling recruitment due to increased soil disturbance and burial of coarse woody debris.[419] These variable results are likely due to several factors, including the different regeneration responses of species following fire, the shade and competition tolerance of those species, site characteristics and rainfall.[420]

411 Bond, R.W. (1944) 'Timber salvage in Victoria'. *Australian Forestry*, 8(1): 13-19.

412 Leverkus, A.B., Buma, B., Wagenbrenner, J., Burton, P.J., Lingua, E., Marzano, R. and Thorn, S. (2021) 'Tamm review: Does salvage logging mitigate subsequent forest disturbances?' *Forest Ecology and Management*, 481: 118721.

413 An obligate seeder is a plant that can readily be killed by fire but regenerate prolifically from seed in the soil ash bed and require fire-free intervals to enable their critical life history traits of plant growth, maturation and senescence. In contrast, resprouters are plants that can survive fire (even if all their foliage is consumed) by vegetatively resprouting new shoots from aerial, basal and below ground buds or pre-bud meristems protected by thick bark.

414 Leverkus, A. B. Gustafsson, L. Lindenmayer, D. B. Castro, J. Rey Benayas, J. M. Ranius, T. and Thorn, S. (2020) 'Salvage logging effects on regulating ecosystem services and fuel loads'. *Frontiers in Ecology and the Environment*, 18: 391-400; Leverkus, A.B. Buma, B. Wagenbrenner, J. Burton, P.J. Lingua, E. Marzano, R. and Thorn, S. (2021) 'Tamm review: Does salvage logging mitigate subsequent forest disturbances?' *Forest Ecology and Management*, 481: 118721.

415 Povak, N.A., Churchill, D.J., Cansler, C.A., Hessburg, P.F., Kane, V.R., Kane, J.T., Lutz, J.A., and Larson, A.J. (2020) 'Wildfire severity and postfire salvage harvest effects on long-term forest regeneration'. *Ecosphere*, 11: e03199.

416 Kitenberga, M., Elferts, D., Adamovics, A., Katrevics, J., Donis, J., Baders, E., and Jansons, A. (2020) 'Effect of salvage logging and forest type on the post-fire regeneration of Scots pine in hemiboreal forests'. *New Forests*, 51: 1069-1085.

417 Castro, J., Allen, C.D., Molina-Morales, M., Marañón-Jiménez, S., Sánchez-Miranda, Á. and Zamora, R. (2011) 'Salvage Logging Versus the Use of Burnt Wood as a Nurse Object to Promote Post-Fire Tree Seedling Establishment'. *Restoration Ecology*, 19: 537-544.

418 Greene, D.F., Gauthier, S., Noël, J., Rousseau, M. and Bergeron, Y. (2006) 'A field experiment to determine the effect of post-fire salvage on seedbeds and tree regeneration'. *Frontiers in Ecology and the Environment*, 4: 69-74.

419 Donato, D.C., Fontaine, J.B., Campbell, J.L., Robinson, W.D., Kauffman, J.B. and Law, B.E. (2006) 'Post-wildfire logging hinders regeneration and increases fire risk'. *Science*, 311: 352.

420 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

Species that have been found to respond positively to salvage logging are light demanding and benefit from disturbance to the tree canopy.[421] Many eucalypt species exhibit this strategy and may benefit from post-fire harvesting provided adequate seed supply exists on site or is added through sowing or planting.[422]

Post-fire re-establishment of vegetation is based on biotic and abiotic factors that vary both spatially and temporally.[423] Climatic variation and local variation in topography and soil can impact regeneration by influencing the occurrence of favourable conditions for the regeneration of species.[424] Further, the regeneration strategy (resprouting or seeding), nature of seed bank (soil-stored versus canopy-stored), and the length of juvenile period (i.e. the time from germination to first fruit set) influence how plant species regenerate and persist through consecutive fires.[425]

However, one disturbance event followed by another in a short period of time may exhaust the regenerative capacity of some species; while the first disturbance promotes germination, the second disturbance may kill the seedlings.[426] The majority of flora species impacted in the 2019/20 wildfires (greater than 90 percent) are fire adapted and have traits that facilitate persistence in post-fire environments.[427] For these species the single fire event is unlikely to increase the risk to species persistence.[428] FCNSW provided anecdotal evidence that high levels of post-harvest regeneration were occurring in burnt areas that were harvested under SSOCs or voluntary measures. Further, FCNSW noted that seedling and coppice regeneration post fire was significant and that this was maintained post-harvest.

The results highlight the risk posed to species not adapted to fire and the future risk of species loss due to future fires that occur at an interval shorter than required for some species to reach reproductive maturity.[429,430] Species considered at medium to high risk following the 2019/20 wildfires include resprouters or obligate seeders deemed vulnerable to recruitment failure due to post-fire drought or subsequent disturbance; for the medium to high risk rated threatened

421 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

422 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

423 Bell, D.T. (1999) 'The process of germination in Australian species.' *Australian Journal of Botany*, 47, 475-517.

424 Mok, H.F., Arndt, S.A., and Nitschke, C.R. (2012) 'Modelling the potential impact of climate variability and change on species regeneration potential in the temperate forests of South-Eastern Australia.' *Global Change Biology*, 18, 1053–1072.

425 Whelan, R.J., Rodgerson, L., Dickman, C.R. and Sutherland, E.F. (2002) *Critical life cycles of plants and animals: developing a process-based understanding of population changes in fire-prone landscapes*. In: Bradstock, R.A., Williams, J.E. and Gill, M.A. (eds). Flammable Australia: The Fire Regimes and Biodiversity of a Continent. Cambridge University Press. p. 94-124.

426 *Ibid*.

427 Godfree, R.C., Knerr, N., Encinas-Viso, F., Albrecht, D., Bush, D., Cargill, D.C., Clements, C., Guja, L.K., Harwood, T., Joseph, L., Lepschi, B., Nargar, K., Schmidt-Lebuhn, A. and Broadhurst, L.M. (2021) 'Implications of the 2019–2020 megafires for the biogeography and conservation of Australian vegetation.' Nature Communications, doi.org/10.1038/s41467-021-21266-5.

428 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

429 Fairman, T.A. Nitschke, C.R. and Bennett, L.T. (2016) 'Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests'. *International Journal of Wildland Fire*, 25: 831-848.

430 Fairman T. Bennett, L. and Nitschke, C.R. (2017) 'Frequent wildfires erode tree persistence and alters stand structure and initial composition of a fire-tolerant subalpine forest'. *Journal of Vegetation Science*, 28: 1151–1165.

flora, reducing post-fire forestry impacts by undertaking surveys of burnt production forests to detect threatened taxa and placing buffers around these taxa has been recommended.[431]

Based on the findings of the desktop assessment of forest type relative recovery potential, the species most at risk in the Coastal IFOA region from regeneration failure associated with multiple wildfires or other disturbances at shorter intervals are likely to include alpine ash and other obligate seeders.[432] Obligate seeder species include canopy trees but also mid- and understorey species. While obligate seeders occur across the Coastal IFOA, such as the alpine ash areas in the Tumut subregion, the forests of the Coastal IFOA are predominantly mixed species forests. Although there are 154 forest types in the Coastal IFOA, only 14 overstorey species are obligate seeders.[433]

Provided adequate seed is available in the crowns of burnt forests it is generally expected that post-fire regeneration will occur.[434] Forestry operations that mandate the post-harvest regeneration of eucalypts, as required under the Coastal IFOA, are likely to ensure that their regeneration will not be negatively impacted in post-fire harvested areas.[435] Further, this relies on applying silvicultural approaches to meet the regeneration requirements of the overstorey species. For example, competition (for example, shade) intolerant species benefit from canopy openings of sufficient size to promote regeneration.[436, 437] Most eucalypts are classified as competition intolerant or very intolerant.[438]

However, unlike for eucalypt regeneration, ensuring adequate regeneration of understorey species is not engrained in practice.[439] This can have implications for plant biodiversity, as well as fauna reliant on understorey vegetation.[440, 441] It can also impact water quality if disturbance to eucalypt and understorey recruitment leads to a loss in plant cover on a site.[442]

No studies were found that had directly assessed forest productivity and health in post-fire salvage harvested forests; studies evaluating forest development post-harvest were generally limited to the early years and focused on the impacts on tree regeneration and competition.[443]

---

431 Gallagher, RV. (2020) *National prioritisation of Australian plants affected by the 2019-2020 wildfire season*. Report to the Commonwealth Department of Agriculture, Water and Environment.

432 Wall, J. (2021) *Recovery potential of forest types to severe wildfire*. 2rog Consulting. A report prepared for the Commission for this review.

433 *Ibid*.

434 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

435 *Ibid*.

436 NSW Department of Environment, Climate Change and Water (2004) *Silviculture guidelines, Private Native Forestry Code of Practice*.

437 Forestry Corporation of NSW (2018) *Native forest silviculture manual.*

438 Florence, R.G. (2004) *Ecology and silviculture of eucalypt forests*. CSIRO Publishing, Melbourne

439 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

440 Law, B., Brassil, T. and Gonsalves, L. (2016) 'Recent decline of an endangered, endemic rodent: does exclusion of disturbance play a role for Hastings River mouse (*Pseudomys oralis*)?' *Wildlife Research*, 43, 482-491.

441 Law, B. Chidel, M. Britton, A. and Threlfall, C. (2018) 'Comparison of microhabitat use in young regrowth and unlogged forest by the eastern pygmy-possum (*Cercartetus nanus*)'. *Australian Mammalogy*, 40: 1–9.

442 Sheridan, G.J., Lane, P.N.J. and Noske, P.J. (2007) 'Quantification of hillslope runoff and erosion processes before and after wildfire in a wet Eucalyptus forest.' *Journal of Hydrology*, 343, 12– 28.

443 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

The Commission's recommended additional measures take into account the application of appropriate silvicultural approaches that are best suited to the dominant overstorey species, and that will promote future high quality wood supply while being cognisant of ecological forest regeneration outcomes.

Weeds and feral animals present a significant threat to recovering flora and fauna

Large and intense fires present a risk for vulnerable native species as they can worsen the impact of other stressors, such as non-native and invasive plants (weeds) and animals.

Recovery is significantly hampered by feral animals and following the 2019/20 wildfires issues are expected to include:[444]

- feral predators such as cats and foxes preying on native wildlife that have survived in burnt habitats
- feral grazers such as deer, horses, rabbits and domestic stock destroying recovering vegetation.

Predation by mammalian predators of native fauna is intensified post-fire by the reduction of vegetation cover, while overgrazing or browsing by introduced herbivores can prevent post-fire vegetation recovery. Often weeds have a competitive advantage over native plants in a post-fire landscape, which can severely restrict the regeneration response of native plants, including eucalypts. The immediate post-fire environment and up to two years following fire, is the key window of opportunity for weed management.

Increasing the control of invasive species is recognised best practice in facilitating post fire ecological restoration. In response to the fires the Australian Government made funding available to Local Land Services in fire-affected areas for the control of invasive plants and animals. Although FCNSW received none of these funds directly, it has collaborated with Local Land Services in some target invasive species control programs.

444 DPIE (2020) *Impact of fires on plants and animals - providing advice for the recovery of biodiversity after fire*. Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/factsheet-impact-of-fires-on-plants-and-animals-200065.pdf

Appendix 1 – Terms of reference

SENSITIVE: NSW CABINET

(Draft) TERMS OF REFERENCE

Coastal IFOA operations post-2019/20 bushfires

In accordance with sections 13(1)(d1) and 13(1)(g) of the *Natural Resources Commission Act 2003*, the Natural Resources Commission has been appointed to advise on pathways back to Forestry Corporation of New South Wales (FCNSW) operating under standard Coastal Integrated Forestry Operations Approval (CIFOA) prescriptions as the NSW public forest estate recovers from the 2019-20 bushfires.

Purpose

The purpose of the engagement is to provide the Minister for Planning and Public Spaces, the Minister for Energy and Environment, and the Deputy Premier and Minister for Regional NSW, Industry and Trade with independent, evidence-based advice on pathways back to FCNSW operating under standard CIFOA prescriptions in forests affected by the 2019/20 bushfires.

The advice should review best available information, and identify information necessary to determine where, when and how it is practicable to commence forestry operations under standard CIFOA conditions while satisfying the purposes of Part 5B of the Forestry Act 2012 and the objectives and outcomes specified in the CIFOA.

The review will inform the responsible Ministers on a recommended way to give effect to the advice of the NRC to manage forestry operations in fire-affected forests following the 2019-20 bushfires.

Scope of advice

The Commission will:

1. review the available scientific evidence on the environmental impacts of forestry operations under the standard CIFOA prescriptions and the site-specific operating conditions (SSOCs) in areas affected by the 2019-20 bushfires, and identify any knowledge gaps or absence of robust scientific evidence. The Commission may engage independent experts to inform its advice.
2. make specific recommendations on pathways back to FCNSW operating under standard CIFOA prescriptions in forests both where SSOCs are in place and elsewhere in fire-affected forests across NSW. This may include consideration of:
    - Severity and extent of the fire in relation to particular areas or ecological communities.
    - Forest recovery criteria.
    - Time since the fire.
    - Staging or prioritising recommencement of standard CIFOA prescriptions to minimise impacts to the environment.
3. recommend, using the best available scientific evidence, best practice approaches to manage forestry operations in fire-affected forests to satisfy the purposes of Part 5B of the *Forestry Act 2012* and the objectives and outcomes specified in the CIFOA, including having regard to the Commission's views on the recovery of the fire-affected forests over time following bushfires.

Where any of the Commission's recommendations may have an impact on FCNSW's ability to meet wood supply, the Commission will consider the implications of such recommendations and advise on their impact on wood supply and the timber industry.

Process
The Commission will consult the agencies on its proposed process and timeline, but it must include the following:

- engaging with FCNSW, EPA, EES and DRNSW during the review process.
- providing preliminary findings to the Ministers within an agreed timeframe. This includes proposed settings put forward by the parties, and the Commission's preliminary findings and recommendations.
- giving FCNSW, EPA, EES and DRNSW opportunities to respond to any preliminary findings and recommendations by the Commission.
- sharing all relevant information with FCNSW, EPA, EES and DRNSW and all requests from the Commission will be shared with relevant agencies.

The contact officers for the relevant agencies are as follows:
EPA: Michael Hood, Director Environmental Solutions, NSW EPA,

EES: Jeremy Black, Remote Sensing & Landscape Science, Science Economics Insights,

FCNSW: Daniel Tuan, General Manager, Hardwood Forests Division,

DRNSW: Nick Milham, Group Director DPI Forestry,

Final advice
The Commission will provide its final advice within three months of the receipt of these terms of reference unless otherwise agreed by Ministers.

The final advice must document the review's findings and recommendations.

Confidentiality
All information presented to the Commission, as well as its reports advice and recommendations, should be treated as Cabinet in Confidence as it is anticipated that this material will inform a Cabinet Submission.

The Minister for Planning and Public Spaces may direct the Commission to produce a public report of its final advice to assist the Ministers to communicate their joint decision subsequent to the review.

Appendix 2 – Pixel 'smoothing' using focal majority approach

Information in this appendix has been supplied by FCNSW for the purposes of this review.

Raster datasets

Rasters are a method of storing, displaying and analysing GIS data. They are comprised of pixels in a regular grid, usually symmetrical in shape (square), as shown in **Figure A2.1**. Rasters are commonly used to store information and data such as photographs taken on phones or digital cameras, images within computer packages, and within GIS they are used for satellite and other remotely sensed imagery, as well as thematic data such as land use classification, forest cover, average rainfall and FESM.

Raster resolution is the pixel size as represented on ground, also known as ground sampling distance, as shown in **Figure A2.1**. Depending on the data being represented, ground sampling distance is extremely important to ensure accurate, relevant, and appropriate use of such data. For example, mean annual temperature often use a large ground sampling distance such as 2 kilometres by 2 kilometres to store and display temperature for a given location.

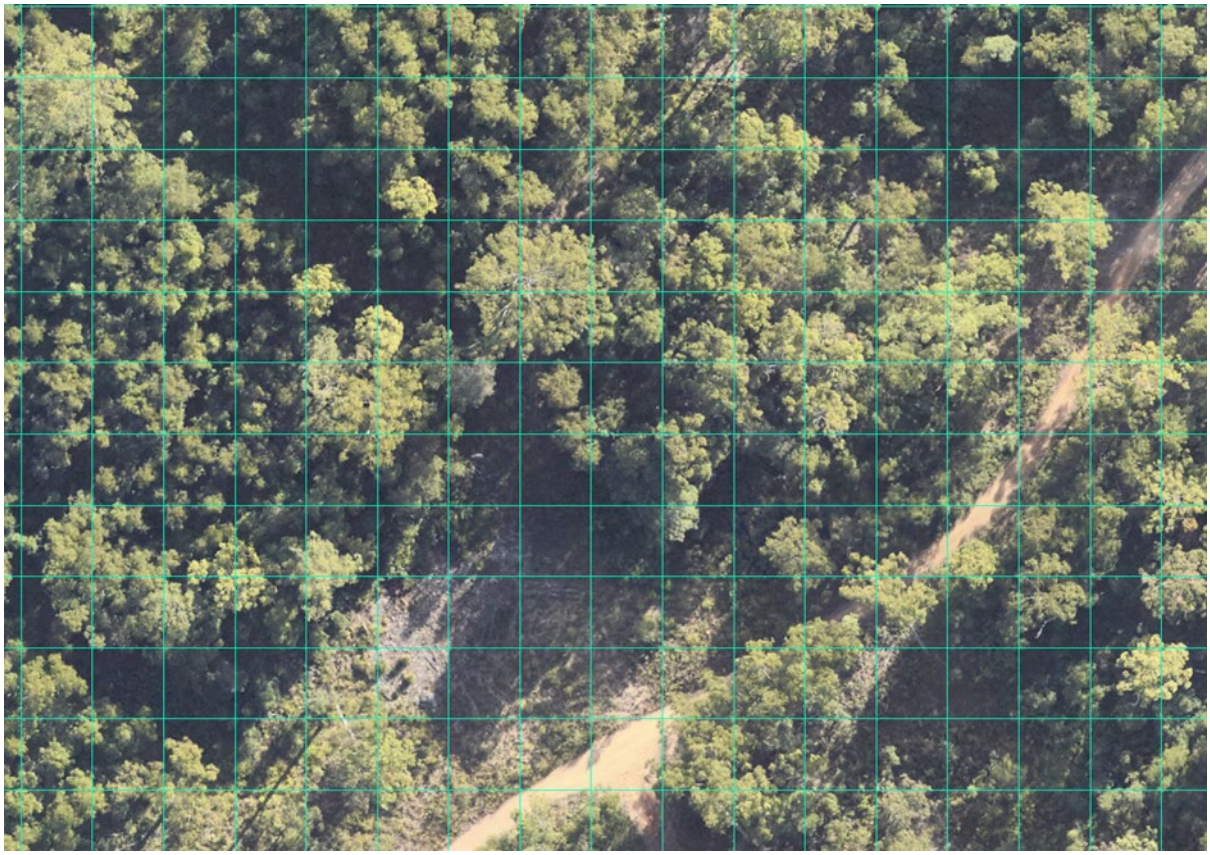

Figure A2.1: An aerial photograph of native forest with an overlying 10 metre by 10 metre grid representing pixel sizes. FESM displays burn severity for each individual pixel across the landscape.

Operational application of FESM

FESM is derived from satellite imagery on a 10 metre by 10 metre ground sampling distance. Analysis of burn intensity is also undertaken at this ground sampling distance, resulting in an extremely precise estimation of a natural process (in this case wildfire) in a landscape context, where one pixel will often represent only one part of a mature tree crown. Where FESM has assessed a change in pre- and post- fire spectral values, these changes are displayed for each

pixel, which often provides significant variation in burn severity in a localised area. Natural variations in forest extent, vegetation cover, ground features such as roads, tracks, water, rocky outcrops and many others, are similarly assessed within FESM for burn severity even though they may not be affected by wildfire, and often further contribute to localised FESM variation.

Land managers often use data stored in rasters to assist in management decisions. However, these decisions are generally made at an ecologically appropriate scale, such as a landscape scale, rather than the ground sampling distance of raster data.

Fire severity across a landscape as modelled in FESM is difficult to interpret on the ground at an operational scale at a 10 metre by 10 metre ground sampling distance, with isolated pixels or groups of pixels, potentially representing one tree rather than a stand of trees. However, using GIS, FESM pixels can be aggregated into the majority fire intensity over a 25-metre radius (**Figure A2.2**), then have small areas less than 0.5 hectares merged into neighbouring polygons providing a smoothed assessment of fire severity across the operational scale (**Figure A2.3**).

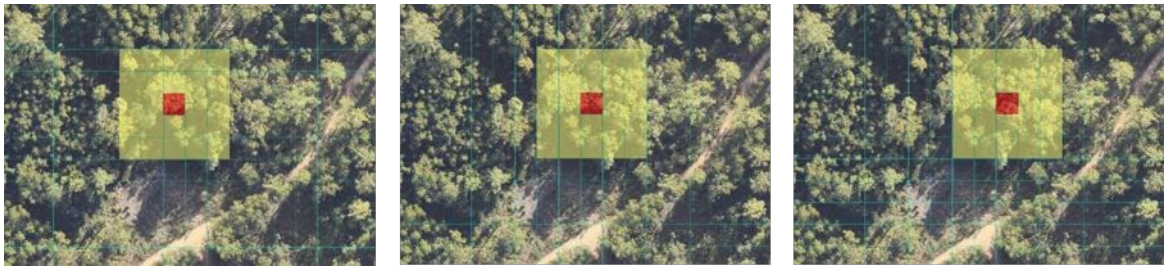

Figure A2.2: The process of pixel 'smoothing' using the focal majority approach, where the processing cell in red is attributed the majority value of all cells within the focal window identified in yellow

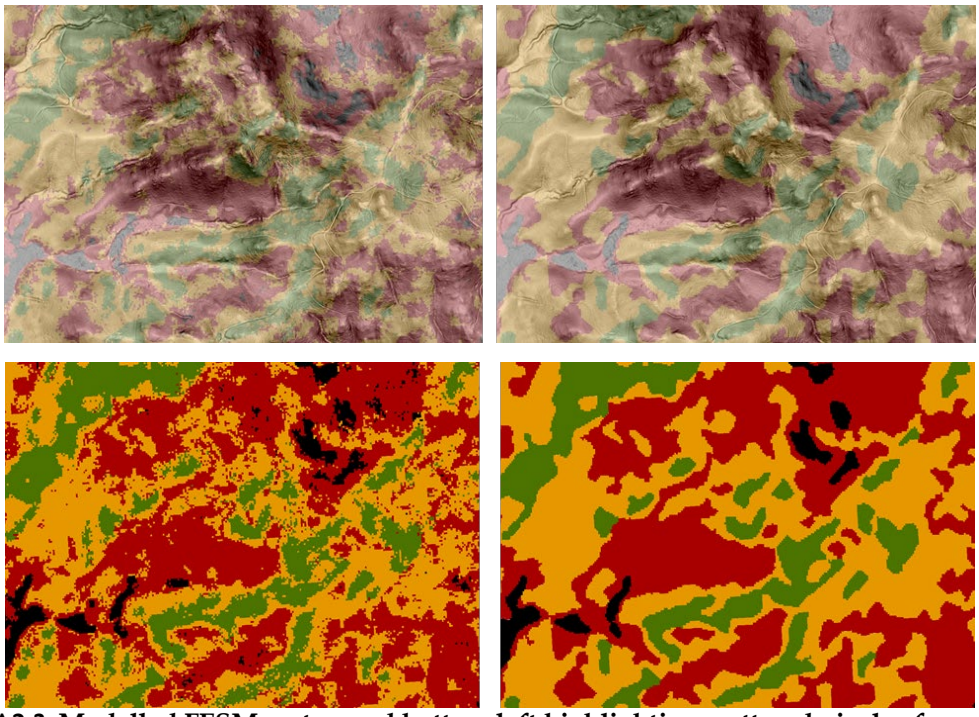

Figure A2.3: Modelled FESM on top and bottom left highlighting scattered pixels of varying fire severity. At top and bottom right the majority FESM with polygons less than 0.5 hectares removed. Both top images have lidar modelled ground surface overlain for context.

Appendix 3 – Alignment of Coastal IFOA outcomes with risk categories

Risk category	Coastal IFOA Outcome
Maintain ecological function and habitat connectivity	▪ Habitat and environmental features are identified and retained to provide refuge, connectivity and to support forest regeneration ▪ Environment features, habitat, landscapes, and communities are identified, and protections are permanently established, to mitigate the impact of the forestry operation ▪ Environment features, habitat and risks are identified to ensure that protections and management actions are implemented to mitigate the impact of the forestry operation ▪ Environment features, habitat and risks are identified, and site-specific protections and management practices are developed to mitigate the impact of the forestry operation
	▪ Woody debris is retained across operational areas to provide shelter and foraging habitat for native species to support their persistence
	▪ Environment features, habitat and risks are identified to ensure that protections and management actions are implemented to mitigate the impact of the forestry operation
	▪ Environmentally significant areas and important habitat are managed during burning operations to maintain their intended, specific environmental values and provide short-term refuge habitat
	▪ Environmentally significant areas are protected during forestry operations to maintain their intended, specific environmental values
	▪ Environment features, habitat, landscapes, and communities are maintained through the implementation of best management practices for pre-harvest burns and post-harvest burns
Maintain persistence of native species	▪ Important trees are retained and protected for shelter and food resources for native species, and to support their persistence.
	▪ Environment features, habitat and risks are identified, and site-specific protections and management practices are developed to mitigate the impact of the forestry operation
	▪ Site-specific measures are implemented to mitigate the impact of the forestry operation on fauna species and their habitat, and to support their persistence ▪ Site-specific measures are implemented to mitigate the impact of the forestry operation on flora species and their habitat, and to support their persistence

Protect of aquatic habitat and water quality	▪ Vegetation adjacent to drainage features and wetlands is protected, and groundcover is retained, to maintain water quality, stream stability, riparian habitat and contribute to habitat connectivity
	▪ Water quality, aquatic habitat and native fish movement are maintained through the implementation of best management practices for roads, tracks, and crossings
	▪ Water quality and aquatic habitat are protected and maintained through the implementation of best management practices ▪ Dust and waste are managed to minimise pollution around operational areas
Promote forest regeneration and structure	▪ Harvesting operations are distributed across the landscape and over time, to support a mosaic of forest age-classes and maintenance of forest structure in the operational area or local landscape area
	▪ Harvested areas are adequately stocked with a natural floristic composition to maintain ecological function and sustainable timber supplies
Monitoring	▪ Monitoring programs are applied at multiple landscape scales to ensure the ongoing effectiveness of the approval in delivering the objectives of the approval and outcome statements ▪ Monitoring, management, and protection measures are identified, planned and implemented for specific native species to support their persistence

Appendix 4 – Consequence and risk statements

Table A4.1: Consequence statements

Consequence category	Consequence
Catastrophic	The cumulative impact of forestry operations in a severely fire-affected landscape may result in irreversible local or widespread impact to a single asset (extinction of species, irreversible loss of function). Severe, long-term impacts to many species or assets over a wide area from which recovery is improbable.
Major	The cumulative impact of forestry operations in a severely fire-affected landscape may result in severe, long-term local or widespread impact to asset(s) from which recovery is very difficult (major declines in species or function; widespread landscape-level impacts).
Moderate	The cumulative impact of forestry operations in a severely fire-affected landscape may result in moderate, short- to medium-term impact to a local asset (local population declines for species but no change in listing category; temporary or local reduction in some functional attributes). Minor impacts to multiple species or assets.
Minor	The cumulative impact of forestry operations in a severely fire-affected landscape may result in minor, short-term, reversible impacts to a local asset (temporary local habitat loss unlikely to impact populations or landscape function).
Insignificant	The cumulative impact of forestry operations in a severely fire-affected landscape may result in negligible impacts to assets.

Table A4.2: Likelihood statements

Likelihood category	Likelihood
Almost certain	There is a very high possibility that the consequence will occur as the extent of the cumulative impact of forestry operations in a severely fires impacted landscape means the consequence is almost certain.
Likely	There is a high possibility that the consequence will occur as the extent of the cumulative impact of forestry operations in a severely fires impacted landscape means the consequence is very likely.
Moderate	There is an equal possibility of the consequence occurring as not occurring. The extent cumulative impact of forestry operations in a severely fires impacted landscape leaves some uncertainty.
Unlikely	There is a low probability the consequence will occur. Given the small extent of the cumulative impact of forestry operations in a severely fires impacted landscape the consequence is unlikely to occur.
Rare	Due to the very small extent of the cumulative impact of forestry operations in a severely fires impacted landscape the consequence is very unlikely to occur

Appendix 5 – IUCN criteria, purpose and example thresholds

IUCN criteria, purpose and example thresholds[445]

	Criterion	Purpose	Example thresholds			
A	Reduction in geographic distribution	Identifies ecosystems that are undergoing declines in area, most commonly due to threats resulting in ecosystem loss and fragmentation	**Time frame for reduction in geographic distribution**		**Endangered**	**Vulnerable**
			Past 50 years		≥ 50%	≥ 30%
			Future 50 years		≥ 50%	≥ 30%
			Past, present or future 50 years		≥ 50%	≥ 30%
			Historical (since 1750)		≥ 70%	≥ 50%
B	Restricted geographic distribution	Identifies ecosystems with small distributions that are susceptible to spatially explicit threats and catastrophes	**Measure of geographic distribution**		**Endangered**	**Vulnerable**
			Extent of area capturing all occurrences (km²): AND at least one of: observed or inferred continuing decline; observed or inferred threatening processes; or ecosystem exists at defined no. of threat defined locations		≤ 20,000 ≤ 5 threat-defined locations	≤ 20,000 ≤ 10 threat-defined locations
			The number of 10×10 km grid cells occupied (area of occupancy) are: AND at least one of: observed or inferred continuing decline; observed or inferred threatening processes; or ecosystem exists at defined no. of threat defined locations		≤ 20	≤ 50
			A very small number of threat-defined locations (generally fewer than 5) AND prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus capable of collapse or becoming critically endangered within a very short time period			Vulnerable
C	Environmental degradation	Identifies ecosystems that are undergoing environmental degradation	**Time frame for environmental degradation**	**Extent**	**Relative severity**	
					≥ 50%	**≥ 30%**
			The past 50 years, next 50 years or any 50-year period based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity	≥ 80%	Endangered	Vulnerable
				≥ 50%	Vulnerable	-

445 After Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P (2017) *Guidelines for the application of IUCN Red List of Ecosystems categories and criteria, Version 1.1.*

IUCN criteria, purpose and example thresholds[445]						
			Since 1750 based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity		**≥ 70%**	**≥ 50%**
				≥ 90%	Endangered	Vulnerable
				≥ 70%	Vulnerable	-
D	Disruption to biotic processes or interactions	Identifies ecosystems that are undergoing loss or disruption of key biotic processes or interactions	**Time frame for disruption to biotic processes or interactions**	**Extent**	**Relative severity**	
					≥ 50%	**≥ 30%**
			The past 50 years, next 50 years or any 50-year period based on change in a <u>biotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity	≥ 80%	Endangered	Vulnerable
				≥ 50%	Vulnerable	-
			Since 1750 based on change in a <u>biotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity		**≥ 70%**	**≥ 50%**
				≥ 90%	Endangered	Vulnerable
				≥ 70%	Vulnerable	-
E	Quantitative analysis that estimates the probability of ecosystem collapse	Allows for an integrated evaluation of multiple threats, symptoms, and their interactions	An ecosystem may be listed under Criterion E if it meets the thresholds for the criterion, a quantitative analysis that estimates the probability of ecosystem collapse to be:	**Endangered**	**Vulnerable**	
				≥ 20% within 50 years	≥ 10% within 100 years	

Appendix 6 – Proposed agency conditions

The Coastal IFOA was not designed to mitigate the risks of harvesting in a severely fire-affected landscape resulting from an unprecedented event like the 2019/20 wildfires. This meant additional measures were required to manage unanticipated risks associated with the extent and severity of the fires.

SSOCs were issued by the EPA in selected areas under Condition 23.4 of the Coastal IFOA. SSOCs was agreed to by the parties as an interim approach, it was not meant as a long-term solution for the ongoing management of risks from forestry in fire-affected areas.

SSOSs required:

- retention of unburned or lightly burned forest in these sites to ensure they can provide ongoing refuge and food for animals that persisted during the fires
- increased protections for landscape features like rainforest, rocky outcrops and heathy vegetation to provide additional shelter and food resources for animals, and appropriate environmental conditions for the regeneration of unique native plants
- increased protections for hollow-bearing trees and important feed trees to ensure more nesting and food resources are retained and protected
- no intensive harvesting permitted in burnt areas to lessen erosion risks and biodiversity impacts
- increased requirements to prevent or minimise erosion and water pollution in local creeks and rivers where fires have removed most of the ground cover and destabilised soils – including: - significant expansion of protections around streams
- stricter limits to reduce the distance water can flow on roads, tracks and log dumps
- stabilise exposed soils during and after harvesting operations.

While the SSOCs increase protections to address key post-fire harvesting risks, they were only meant to be applied at a site-scale and on a case-by-case basis.

Acknowledging the issues associated with establishing and implementing the SSOCs, and noting the SSOCs are still operational in some state forests, agencies have proposed or are implementing additional prescriptions:

- In June 2020, FCNSW published an assessment of the impact of the 2019/20 fire season on biodiversity, soil and water values and implications for harvesting in native state forest.[446] From this FCNSW developed a suite of additional precautionary conditions that it considered could be applied in fire-affected areas to allow the resumption of harvesting.
- In response, the EPA sought expert advice[447] on whether the Coastal IFOA, the Coastal IFOA with SSOCs, or FCNSW's 2020 proposal would adequately mitigate risks of forestry operations in severely fire-affected landscape. The advice that EPA received recommended a range of options that primarily relate to settings impacting biodiversity,

446 FCNSW (2020) *2019-20 Wildfires – Environmental Impacts and Implications for timber harvesting in NSW State Forest*.

447 Smith, A.P. (2020) *Review of CIFOA mitigation conditions for harvesting in burnt landscapes*. A report to the EPA.

particularly arboreal gliders. These recommendations were proposed to be applied across the full extent of burnt landscapes where harvesting is proposed.

- In February 2021, FCNSW proposed additional voluntary measures for operations[448] in the South Coast and Eden subregions only, and are currently operating under these, in addition to standard Coastal IFOA prescriptions. These additional voluntary measures were informed by FCNSW's earlier assessment in 2020, as well as further considerations including some of the recommendations proposed by the EPA.[449]

The EPA considers the voluntary measures cannot be enforced as a legal instrument.[450] The EPA has further advised the Commission that it proposed a suite of enforceable measures to apply in operations in burnt areas going forward until the Commission's advice was available as part of this review. To help understand the strengths and limitations of the proposals, the Commission engaged experts to scientifically and critically review the FCNSW proposal (2020) and advice provided to the EPA.[451] The review found:

- The advice provided to the EPA had many shortcomings, including several errors in the interpretation of scientific references and the exclusion of key studies with contradictory perspectives on the impact of timber harvesting on fauna. The review identified an assumption error underpinning the analysis (i.e., point-based assessment that assumes homogeneity in the post-fire and harvesting environment) that would likely lead to the analysis overestimating the impacts of forestry operations in fire-affected landscapes. Further, the review noted the advice did not consider the driving influence of spatial and temporal scales.
- The multi-scale assessment presented in FCNSW's 2020 report and its use of a wide range of literature to identify and argue key points were considered appropriate. However, the review highlights several weaknesses in the report, including the lack of detail of some recommendations and the lack of consideration of cumulative impacts of fine-scale decisions over time and space.

The review also highlighted several critical matters not addressed in either proposal, including:

- the habitat amount and configuration thresholds around riparian buffer widths
- tree and habitat retention patch size
- the ratio of recruitment trees to habitat or hollow-bearing trees[452]
- the overall amount of disturbed forest that should be harvested.

---

448 FCNSW (2021) *Post-fire Standard Operating Procedure (SOP) - FCNSW Voluntary CIFOA Supplementary Measures for Fire Affected Landscapes*.
- FCNSW (2021b) Post-Fire Planning Assessment Report. Template.
- FCNSW (2021c) Post-fire Harvest and Haul Plan. Template.
- FCNSW (2021d) Post-fire SOP: A Method to Assess Post Fire Groundcover Recovery.
- FCNSW (2021e) Post-fire SOP: Post-Fire LLA Offset Mapping.
- FCNSW (2021f) Post-Fire Tree Retention Guide – Southern. [Note: the Commission has not obtained a copy of this document].

449 Smith, A.P. (2020) *Review of CIFOA mitigation conditions for harvesting in burnt landscapes.* A report to the EPA.

450 EPA (2021) *Update on forestry operations and regulatory activities, February 2021.* Available at: https://www.epa.nsw.gov.au/your-environment/native-forestry/bushfire-affected-forestry-operations/update-february-2021.

451 Nitschke, C. (2021) *Critical review of reports by Smith (2020) and Forestry Corporation of NSW (2020)*. University of Melbourne. A report provided to the Commission for this review.

452 The SSOCs issued by the EPA directs the retention of a minimum 10 late-stage (largest or less than 60 centimetres diameter at breast height) trees.

The Commission has considered the detailed findings of the critical review,[453] the findings and management implications from the literature review,[454] and the different measures proposed or included in SSOCs, FSNSW 2020 report, Smith's 2020 report, the voluntary measures FCNSW proposed in February 2021 and compared these with existing prescriptions. This work has informed the additional measures proposed by the Commission in **Section 5.5**. Key literature underpinning the Commission's approach is included in **Chapter 7**.

The Commission considers that there are areas where settings could be enhanced to capture best practices identified in national and international literature. For example:

- multiscale assessment, including across tenures, is critical in fire-affected landscapes and ideally requires spatial analysis to determine where ecosystem legacies are and how best to meet species and habitat requirements
- building from this, the amount of the fire-affected landscape that should be retained, particularly the retention of ecosystem legacies
- recognition of the variability of wildfire impacts at multiple scales and critical importance of retaining unburnt areas
- actively tracking and managing forest regeneration including overstorey and groundcover recovery
- importance of considering past disturbance history and impact of climate change when planning forestry operations
- key areas where further research and monitoring is required (**Section 4.5**).

453 Nitschke, C. (2021) *Critical review of reports by Smith (2020) and Forestry Corporation of NSW (2020)*. University of Melbourne. A report provided to the Commission for this review.

454 Nitschke, C., Hammond, K., Johnson, J., Singh, A. and Wagner, B. (2021) *Literature review and a desktop analysis of approaches to regulate and manage forestry operations post wildfire*. University of Melbourne. A report provided to the Commission for this review.

Appendix 7 – Fauna species assessed to date

Table A7.1: Fauna species assessed to date showing if they are focal fauna species under the Coastal IFOA monitoring program for species occupancy

Common name	Species	Coastal IFOA monitoring program focal fauna species (Table A7.2)?
Mammals		
Rufous bettong	*Aepyprymnus rufescens*	Yes
Eastern pygmy-possum	*Cercartetus nanus*	-
Koala	*Phascolarctos cinereus*	Yes
Spotted-tailed quoll	*Dasyurus maculatus*	Yes
Southern brown bandicoot (eastern)	*Isoodon obesulus obesulus*	Yes
Yellow-bellied glider	*Petaurus australis australis*	Yes
Squirrel glider	*Petaurus norfolcensis*	Yes
Brush-tailed phascogale	*Phascogale tapoatafa tapoatafa*	-
Long-nosed potoroo	*Potorous tridactylus*	Yes
White-footed dunnart	*Sminthopsis leucopus*	-
Red-legged pademelon	*Thylogale stigmatica*	-
Birds		
Rufous scrub-bird	*Atrichornis rufescens*	Yes
Glossy black-cockatoo	*Calyptorhynchus lathami*	Yes
Varied sittella	*Daphoenositta chrysoptera*	Yes
Barking owl	*Ninox connivens*	Yes
Powerful owl	*Ninox strenua*	Yes
Masked owl	*Tyto novaehollandiae*	Yes
Sooty owl	*Tyto tenebricosa*	Yes
Bats		
Eastern false pipistrelle	*Falsistrellus tasmaniensis*	Yes
Golden-tipped bat	*Kerivoula papuensis*	-
Corben's long-eared bat	*Nyctophilus corbeni*	-
Greater broad-nosed bat	*Scoteanax rueppellii*	-
Eastern cave bat	*Vespadelus troughtoni*	-
Frogs		
Stuttering frog	*Mixophyes balbus*	Yes
Giant barred frog	*Mixophyes iteratus*	Yes

Table A7.2: Coastal IFOA monitoring program focal fauna species[455]

Species	
Mammals	Nocturnal birds
Koala	Barking owl
Long-nosed bandicoot	Masked owl
Long-nosed Potoroo	Powerful owl
Rufous bettong	Boobook owl
Southern brown bandicoot	Sooty owl
Spotted-tailed quoll	Diurnal birds
Squirrel glider	Brown treecreeper
Yellow-bellied glider	Glossy black cockatoo
Greater glider	Varied sittella
Sugar glider	Rufous scub-bird
Microbats	Noisy friarbird
Eastern false pipistrelle	Frogs
Eastern freetail-bat	Giant barred frog
Greater broad-nosed bat	Stuttering frog
Southern myotis	
Yellow-bellied sheathtail bat	
Grey-headed flying fox	

455 Natural Resources Commission (2020) *Coastal IFOA Monitoring Program - Species Occupancy.* Available at: https://www.nrc.nsw.gov.au/ifoa-mer-biodiversity.

Appendix 8 – Predicted suitable habitat impacted by fire

Table A8.1 presents analysis conducted by the University of Wollongong for the Commission for this review. The areas were derived from considering the patterns of exposure of species' predicted suitable habitat to the 2019/20 wildfires, which were then investigated to determine levels of exposure to combinations of high or extreme severity fire, logging and high wildfire frequency.

Key points about this table include:[456]

- fire history mapping used covered a period of 50 years (from 1970)
- harvesting history mapping used covered a period of 20 years (from 2000)
- high frequency fire refers to greater than four wildfires in the 50-year period before 2019/20
- species habitat suitability mapping for all species excluding koala were obtained from Saving our Species Program and Macquarie University (n.d.) *Climate Refugia NSW*. Available at: https://nswclimaterefugia.net//.
- koala habitat mapping available on the SEED portal (https://datasets.seed.nsw.gov.au/anzlic_dataset/koala-habitat-information-base-habitat-suitability-models-v1-0) was modified by the University of Wollongong by applying expert knowledge on habitat suitability thresholds to derive the 'habitat suitability above threshold' used in the analysis.

456 Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

Table A8.1: Area of predicted suitable habitat in the Coastal IFOA forest extent for selected threatened fauna species affected by the 2019/20 wildfires and / or logging[457]

Common name	Species	Area of predicted suitable habitat in the Coastal IFOA forest extent (km²)									
		Total	Burnt 2019/20	High & extreme fire severity	Logged	Logged & burnt 2019/20	Logged & burnt high or extreme severity 2019/20	High fire frequency pre 2019/20	High fire frequency post 2019/20	High or extreme fire frequency & severity post 2019/20	Logged & high or extreme fire frequency & severity post 2019/20
Rufous Bettong	*Aepyprymnus rufescens*	41,800	19,974	7,009	1,580	854	292	2,194	4,513	1,600	46
Eastern Pygmy-possum	*Cercartetus nanus*	44,159	20,478	9,191	1,655	953	431	2,297	4,571	1,837	88
Spotted-tailed Quoll	*Dasyurus maculatus*	78,363	36,212	15,233	2,324	1,381	578	4,302	8,402	3,289	111
Southern Brown Bandicoot (eastern)	*Isoodon obesulus obesulus*	5,565	3,096	1,144	514	394	165	410	949	356	55
Yellow-bellied Glider	*Petaurus australis australis*	71,406	35,164	14,177	2,784	1,683	710	4,618	9,078	3,536	158
Squirrel Glider	*Petaurus norfolcensis*	34,007	10,678	4,498	1,029	294	145	2,069	3,408	1,164	17
Brush-tailed Phascogale	*Phascogale tapoatafa tapoatafa*	32,799	12,477	5,147	1,380	633	292	2,063	3,527	1,298	65
Long-nosed Potoroo	*Potorous tridactylus*	47,799	25,092	9,666	2,366	1,414	582	3,174	6,445	2,495	148
White-footed Dunnart	*Sminthopsis leucopus*	14,310	8,905	4,637	801	644	326	1,252	2,438	1,165	108
Red-legged Pademelon	*Thylogale stigmatica*	23,822	13,381	4,828	1,436	955	393	1,192	2,634	1,052	107
Koala	*Phascolarctos cinereus*	59,800	24,059	10,046	2,541	1,515	640	2,512	4,957	1,857	139
Rufous Scrub-bird	*Atrichornis rufescens*	17,673	10,312	3,283	767	561	199	789	1,823	658	27
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	71,610	33,628	13,432	2,547	1,534	637	4,835	9,242	3,548	155

[457] Bradstock, R., Bedward, M. and Price, O. (2021) *Risks to the NSW Coastal Integrated Forestry Operations Approvals posed by the 2019/20 fire season and beyond*. Working draft dated May 2021. A draft report to the NSW Natural Resources Commission, prepared by the Centre for Environmental Risk Management of Bushfires, University of Wollongong.

Common name	Species	Area of predicted suitable habitat in the Coastal IFOA forest extent (km²)									
		Total	Burnt 2019/20	High & extreme fire severity	Logged	Logged & burnt 2019/20	Logged & burnt high or extreme severity 2019/20	High fire frequency pre 2019/20	High fire frequency post 2019/20	High or extreme fire frequency & severity post 2019/20	Logged & high or extreme fire frequency & severity post 2019/20
Varied Sittella	*Daphoenositta chrysoptera*	83,010	36,002	15,344	2,569	1,538	642	4,824	9,264	3,611	157
Barking Owl	*Ninox connivens*	28,940	8,292	3,699	888	268	138	1,668	2,544	791	11
Powerful Owl	*Ninox strenua*	82,818	37,437	15,372	2,865	1,726	731	5,007	9,572	3,698	160
Masked Owl	*Tyto novaehollandiae*	73,109	35,221	14,298	2,658	1,606	666	4,987	9,494	3,651	156
Sooty Owl	*Tyto tenebricosa*	56,880	31,447	12,466	2,451	1,502	611	4,261	8,520	3,339	153
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	73,406	34,687	14,512	2,287	1,482	590	4,411	8,582	3,336	132
Golden-tipped Bat	*Kerivoula papuensis*	44,458	23,489	8,726	1,981	1,147	456	2,821	5,960	2,268	112
Corben's Long-eared Bat	*Nyctophilus corbeni*	8,234	2,228	1,063	-	-	-	124	255	74	-
Greater Broad-nosed Bat	*Scoteanax rueppellii*	56,696	27,123	10,372	2,219	1,246	485	4,157	7,783	2,880	94
Eastern Cave Bat	*Vespadelus troughtoni*	21,127	7,084	2,887	373	106	64	1,423	2,392	872	9
Stuttering Frog	*Mixophyes balbus*	31,293	16,794	5,375	1,394	818	268	1,723	3,810	1,257	44
Giant Barred Frog	*Mixophyes iteratus*	23,013	11,320	3,818	1,354	686	233	1,026	2,112	676	34