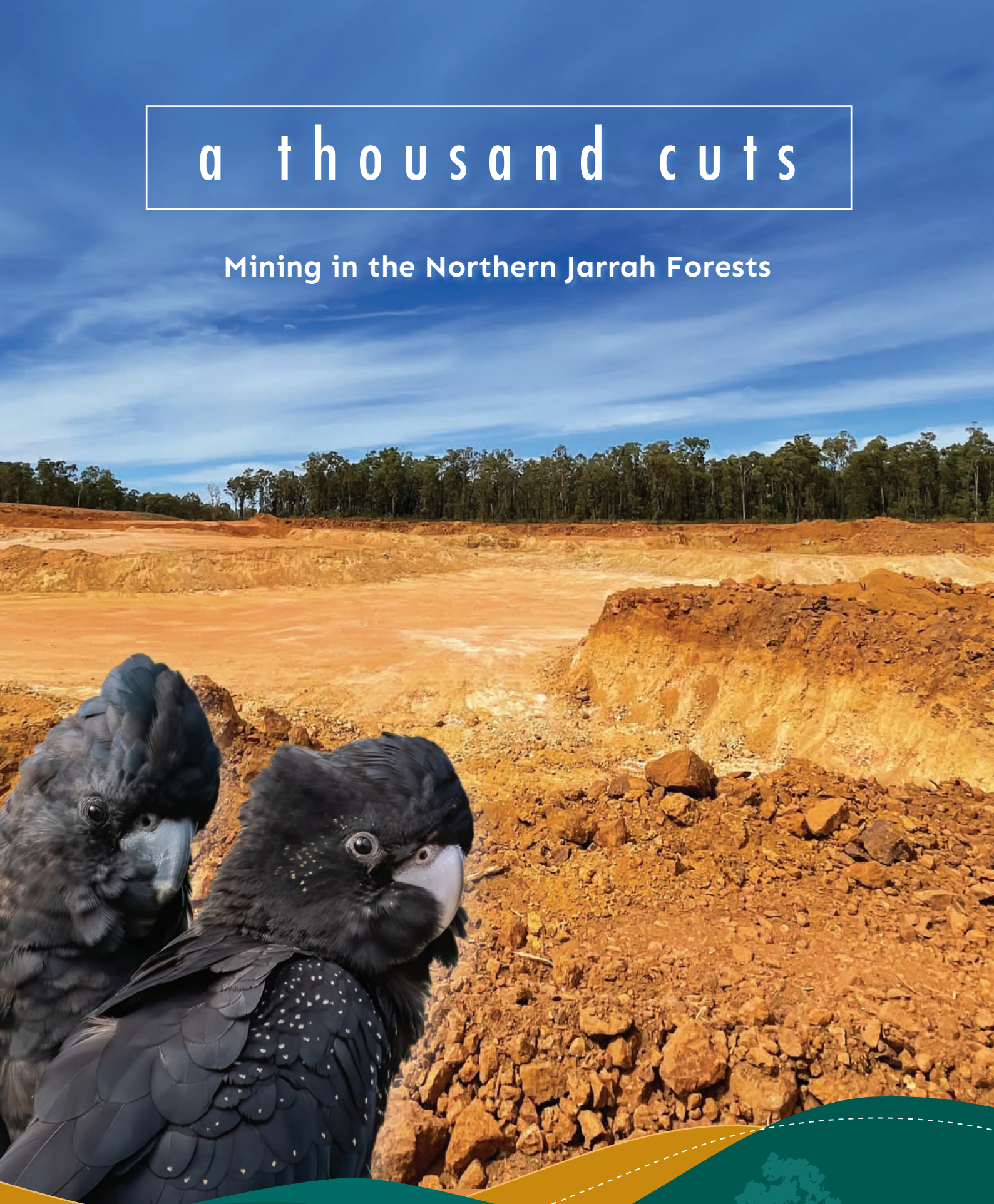
a thousand cuts

Mining in the Northern Jarrah Forests



WA FOREST ALLIANCE

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Northern Jarrah Forests

WA's peak environment and forest conservation groups have published this report to provide information and analysis regarding the impacts of bauxite mining in the Northern Jarrah Forests. The Northern Jarrah Forests are one of a handful of Australian ecosystems under particular threat of collapse due to climate change. They are highly diverse and home to an incredible number and variety of plants and animals as well as being vital to water quality and supply for the Perth metropolitan region and South West forests.

West Australians are increasingly concerned with the protection of this magnificent place. The report provides both an overview and high level of detail on the region and the threat posed by proposed mining expansions. It will assist in advocacy, research and communication as we work towards the protection of the Northern Jarrah Forests in secure conservation areas.

WAFA, Wilderness Society and Conservation Council of Western Australia recognise Aboriginal and Torres Strait Islanders as the Traditional Owners and Custodians across Australia. We acknowledge that Sovereignty was never ceded, and that Australia always was and always will be, Aboriginal land.

Title: A Thousand Cuts – Mining in the Northern Jarrah Forests

Map production and geospatial analysis undertaken in consultation with The University of Western Australia

Design: Donna Chapman, Red Cloud Design

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Copies of the report can be found and downloaded on the WA Forest Alliance website at www.wafa.org.au/get-informed/

Cover photos: Willowdale bauxite mine (Jess Beckerling); Forest red-tailed black cockatoos (Philippa Beckerling)

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EXECUTIVE SUMMARY

The Jarrah forests of the South West of Western Australia are a key part of a Global Biodiversity Hotspot that is under enormous cumulative pressure from a variety of sources including native forest logging, mining, agriculture, urban development, dieback, prescribed burning and climate change.

A key risk of climate change, identified in the IPCC's Sixth Assessment Report, is that the Northern Jarrah Forest will collapse or transition to a new ecosystem without its characteristic and framework species. However, the risk can be substantially reduced by avoiding and reducing clearing and forest degradation from inappropriate forest management practices and land use.

The primary cause of deforestation in Western Australia's South West forests is bauxite mining. Bauxite mining has cleared at least 32,130 hectares of publicly owned forest (80 times the size of Perth's Kings Park) and fragmented 92,000 to 120,000 hectares of the Northern Jarrah Forest up to December 2019, and the rate is accelerating - of that 32,130 hectares, 11,290 hectares (more than a third) were cleared between 2010 and 2020.

In recognition of the critical role that forests play in mitigating and building resilience to climate change, more than 100 countries, including Australia agreed to end deforestation by 2030 at the UN Climate Change Conference COP 26 in Glasgow in 2021. But bauxite miners Alcoa and South32 (Worsley) now seek approval to clear a further 11,109 hectares and fragment another 70,211 hectares. It has been estimated that eventually bauxite mining will clear up to 83,000 hectares and fragment 337,000 hectares. Most of the forest between Collie and Armadale is expected to be fragmented by bauxite mining by 2060.

It is unclear how much forest has been cleared on private land as a result of bauxite mining or for other reasons. Western Australia does not keep central or complete records of the total amount of deforestation and forest degradation that is happening and the contribution that each sector makes to that total. This is wholly inadequate and needs a major overhaul to provide for accurate data on which to base management decisions. The Western Australian government conceded this in 2019 and improvement is a work in progress.

The Northern Jarrah Forest, including the areas that Alcoa and South32 now seek approval to clear, is habitat for threatened species including mainland quokkas, Carnaby's cockatoos, Baudin's cockatoos and Forest red-tailed black cockatoos. For every one of those species, habitat loss and fragmentation is a major contributor to their decline. Further, the Recovery Plans for each species refer specifically to threat from mining. There is no robust evidence that more habitat can be lost without significant adverse impacts on these threatened species. What remains of their existing habitat needs to be conserved if they are to survive. The Recovery Plans have not been effective in achieving this, not least because no funding is specifically allocated for implementing them.

Bauxite mining companies 'rehabilitate' their mine sites when mining is finished, but there are many important differences between intact forest and rehabilitated mine sites. Forest reduces carbon emissions, decreases temperature, reduces rainfall decline and provides fauna habitat – and intact forest significantly outperforms rehabilitated mine sites on all of those measures.

Given the extent of the pressure on the Northern Jarrah Forest, a strategic assessment of the cumulative effects on the region by the Environmental Protection Agency is merited to inform future management decisions. There are various mechanisms in the Environmental Protection Act 1986 that allow the Environmental Protection Agency to do this.

Carnaby's black cockatoo *Photo: Kerem Kanadikirik (Kero) Insta: what_kero_seen*

Public and Parliamentary scrutiny of the State Agreements between the Western Australian government and the bauxite mining companies is constrained because the agreements are not available in an up to date consolidated form except upon request to the Department of Jobs, Tourism, Science and Innovation. Following repeated questions in Parliament the McGowan government committed in June 2021 to making up to date consolidated versions of State Agreements publicly available, but has not yet done so.

This report makes five recommendations:

1. That no further clearing or fragmentation of native forest in the Northern Jarrah Forest for mining be authorised
2. That the Environmental Protection Agency undertake a strategic assessment of the potential cumulative impacts of past, current and proposed activities and developments (including but not limited to bauxite mining, logging and prescribed burning) on the Northern Jarrah Forest
3. That there be a WA government inquiry into:
    a. The efficacy of current processes (including Recovery Plans and Habitat Protection Plans) in arresting the decline of threatened native forest species including mainland quokkas, Carnaby's cockatoo, Baudin's cockatoo and Forest red-tailed black cockatoo
    b. The obstacles to implementing the recovery actions recommended by those processes
    c. Whether there is a need for an emergency plan to arrest the decline of threatened native forest species including mainland quokkas, Carnaby's cockatoo, Baudin's cockatoo and Forest red-tailed black cockatoo
4. That the WA government create and maintain an up to date, publicly accessible central record of native vegetation and biodiversity data that shows and tracks its extent and condition across the State, including showing and tracking the proportion cleared in each bioregion by each sector
5. That the WA government immediately make up to date consolidated versions of all State Agreements publicly available.

Dwellingup forest in the current proposed mining expansion area. *Photo: Jess Beckerling*

THE NORTHERN JARRAH FOREST[1]

KEY POINTS:

The Jarrah Forest is a key part of a Global Biodiversity Hotspot that is under enormous pressure.

The Northern Jarrah Forest grows on the Darling Plateau in a belt some 250 kilometres long, from north of Toodyay to south of Collie, between 30 kilometres and 70 kilometres wide and 40 kilometres from the coast.

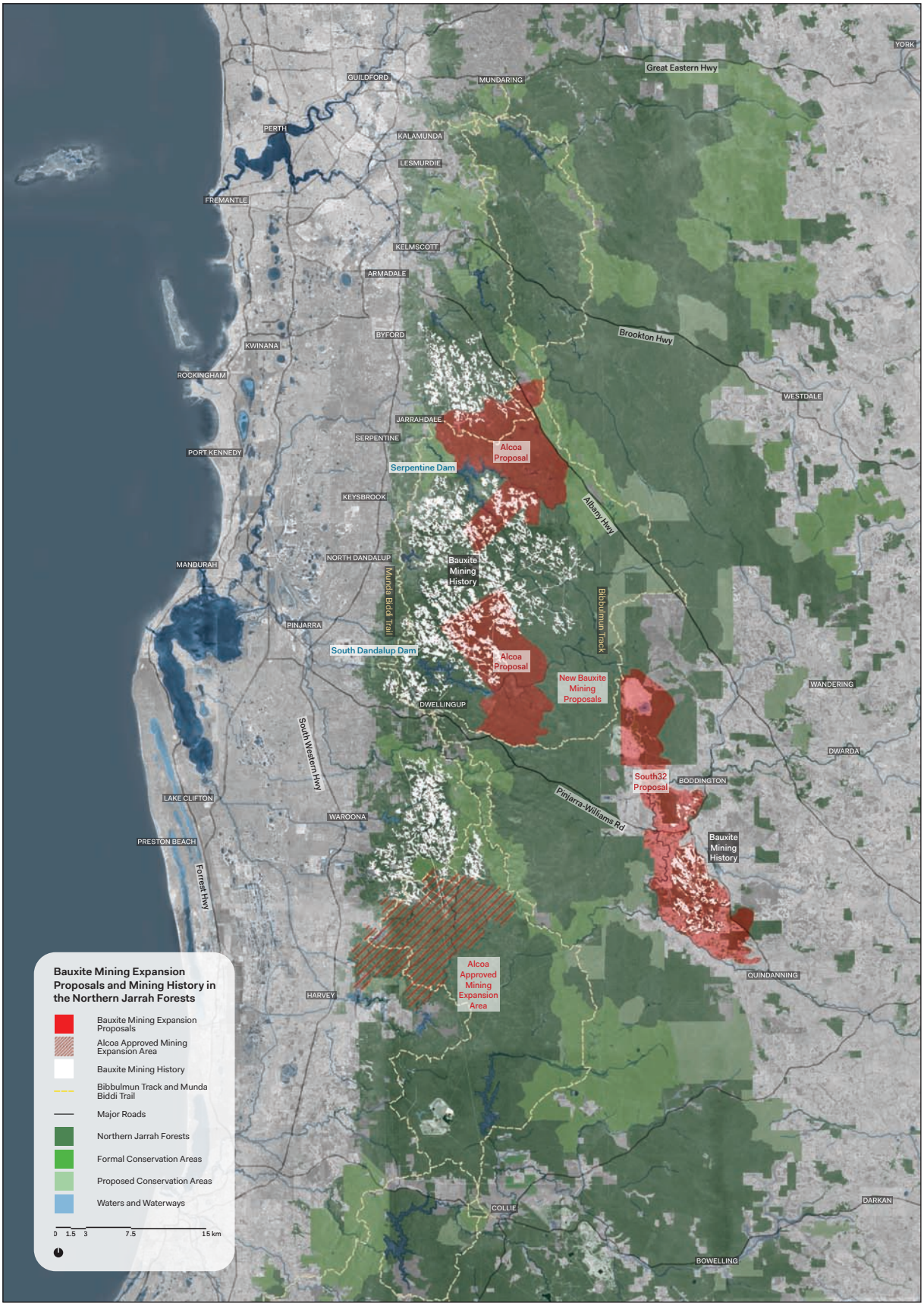
See Map 1, Bauxite mining expansion proposals and mining history in the Northern Jarrah Forests, page 7.

In 1989 the annual rainfall ranged from 750 to 1400 millimetres.[2] Jarrah-Marri forest on laterite gravels lies in the western areas where rainfall is higher. Wandoo-Marri woodlands on clayey soil lie in the eastern areas where rainfall is lower. Rivers with dams or reservoirs provide drinking water storage and irrigation for agriculture.

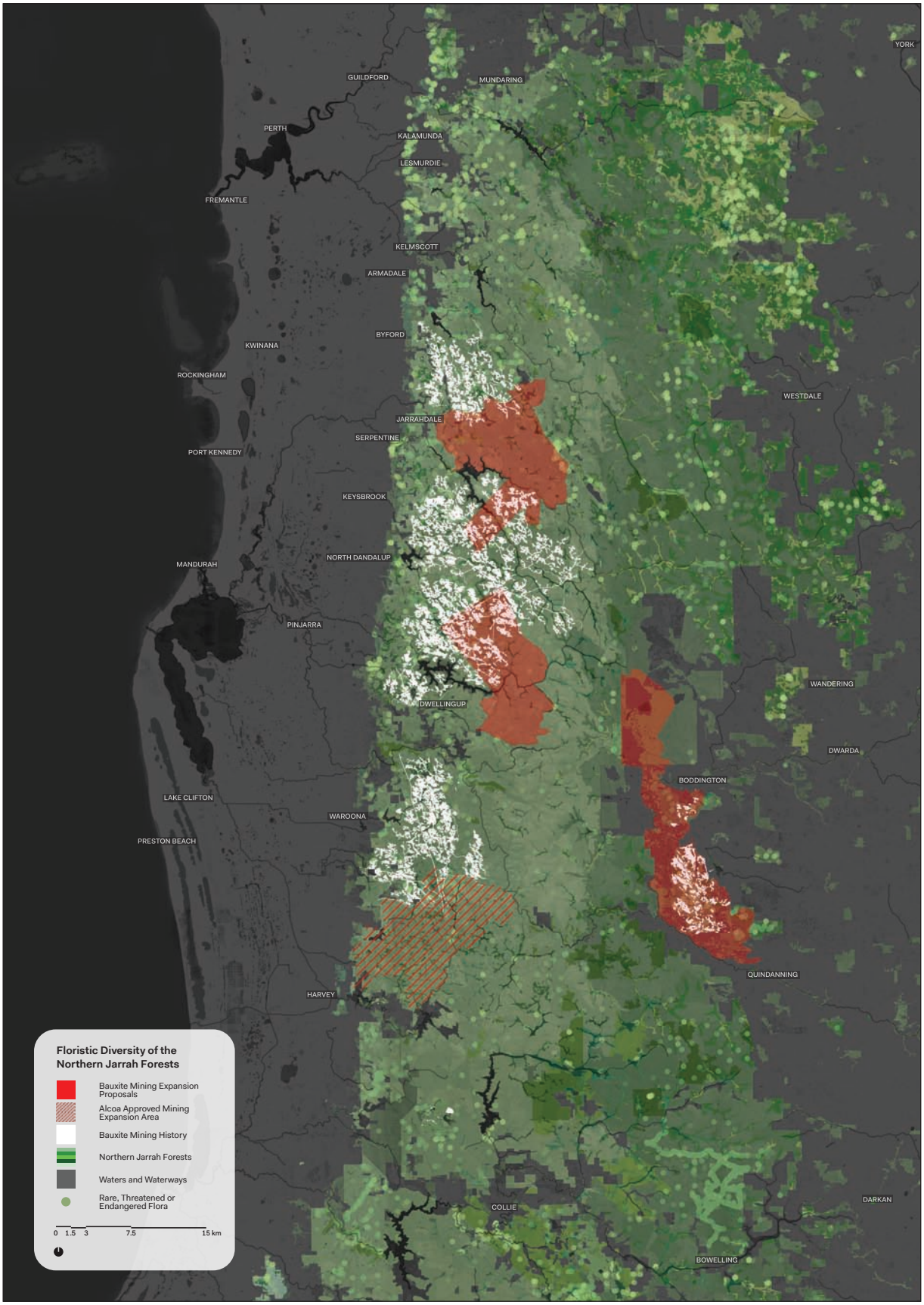
The Jarrah Forest (comprising both the Northern and Southern Jarrah Forests) is a key component of one of the biodiversity hotspots of the world.[3] Its animal and plant diversity ranks alongside tropical rainforest. It has species that are endemic to the South West forest region, including its namesake Jarrah (*Eucalyptus marginata*).

More than 780 native plant species range across the Jarrah Forest's diverse environmental conditions. In addition to the dominant Jarrah and Marri there are Sheoak, Banksia and Persoonia. Shrubs include *Papilionaceae, Proteaceae, Myrtaceae* and *Mimosaceae*. At ground level there are *Anthericaceae, Dasypogonaceae, Leguminosae, Orchidaceae, Apiaceae, Epacridaceae, Asteraceae, Restionaceae, Cyperaceae* and *Liliales*.

See Map 2, Floristic diversity of the Northern Jarrah Forests, page 8.



Map 1 – Bauxite mining expansion proposals and mining history in the Northern Jarrah Forests



Map 2 – Floristic diversity of the Northern Jarrah Forests

Chuditch. *Photo: Clarissa Human*

The Jarrah Forest is home to at least 235 vertebrate species excluding fish. Invertebrate diversity is thought to be in the tens of thousands, with many species still not yet formally described and named. Fungi populations are so diverse that over 100 species have been identified in single study sites.

The Jarrah Forest contains two wetlands of national significance and several rivers of subregional significance. There are many rare or threatened species including species of orchid, frog species, birds (including three black cockatoo species and Muir's corella) and mammals (including Southern brown bandicoot, Chuditch, Dibbler, two species of Phascogale, mainland Quokka, Numbat, Woylie, Tammar wallaby and Western ringtail possum).

But the Northern Jarrah Forest is under enormous pressure. It has been logged and cleared for mining, forestry, grazing, agriculture, residential and urban purposes. It contains dieback and it is burnt under the WA government's prescribed burning regime. In addition, rainfall in South West WA has declined by about 20% since the 1970s and that decline is projected to continue.[4] The Northern Jarrah Forest was one of the places most affected by the tree deaths that occurred in the South West in 2010/11 as a result of heatwave and drought.[5] All of these pressures have a cumulative impact. The Global Biodiversity Hotspot that we have in Perth's backyard is vulnerable to escalating threats.

The fungus is *Omphalotus nidiformis* (the glowing ghost fungi) and grows across most of Australia's southern forests. The insect is a Sunfly or Heleomyzidae family and is especially associated with fungi. *Photo: Jinni Wilson*

Numbats. *Photo: Lyn Alcock*

CLEARING FOR BAUXITE MINING IN THE NORTHERN JARRAH FOREST

KEY POINTS:

At least 32,130 hectares of the Jarrah, Marri, Wandoo and associated ecosystems on publicly owned land in the Northern Jarrah Forest have been cleared, and 92,000 to 120,000 hectares fragmented, for bauxite mining.

The rate is accelerating. Of that amount, 11,290 hectares were cleared between 2010 and 2020.

Native vegetation data sets maintained by the WA Department of Primary Industries and Regional Development (DPIRD) reveal that there was an overall decline in WA's tall and medium forests, as defined by Beard et al., of 18,069 hectares between 2010 and 2020.

11,290 hectares of this decline is attributable to bauxite mining.

Bauxite mining companies, Alcoa and South32 (Worsley), now propose to clear a further 11,109 hectares and fragment a further 70,211 hectares.

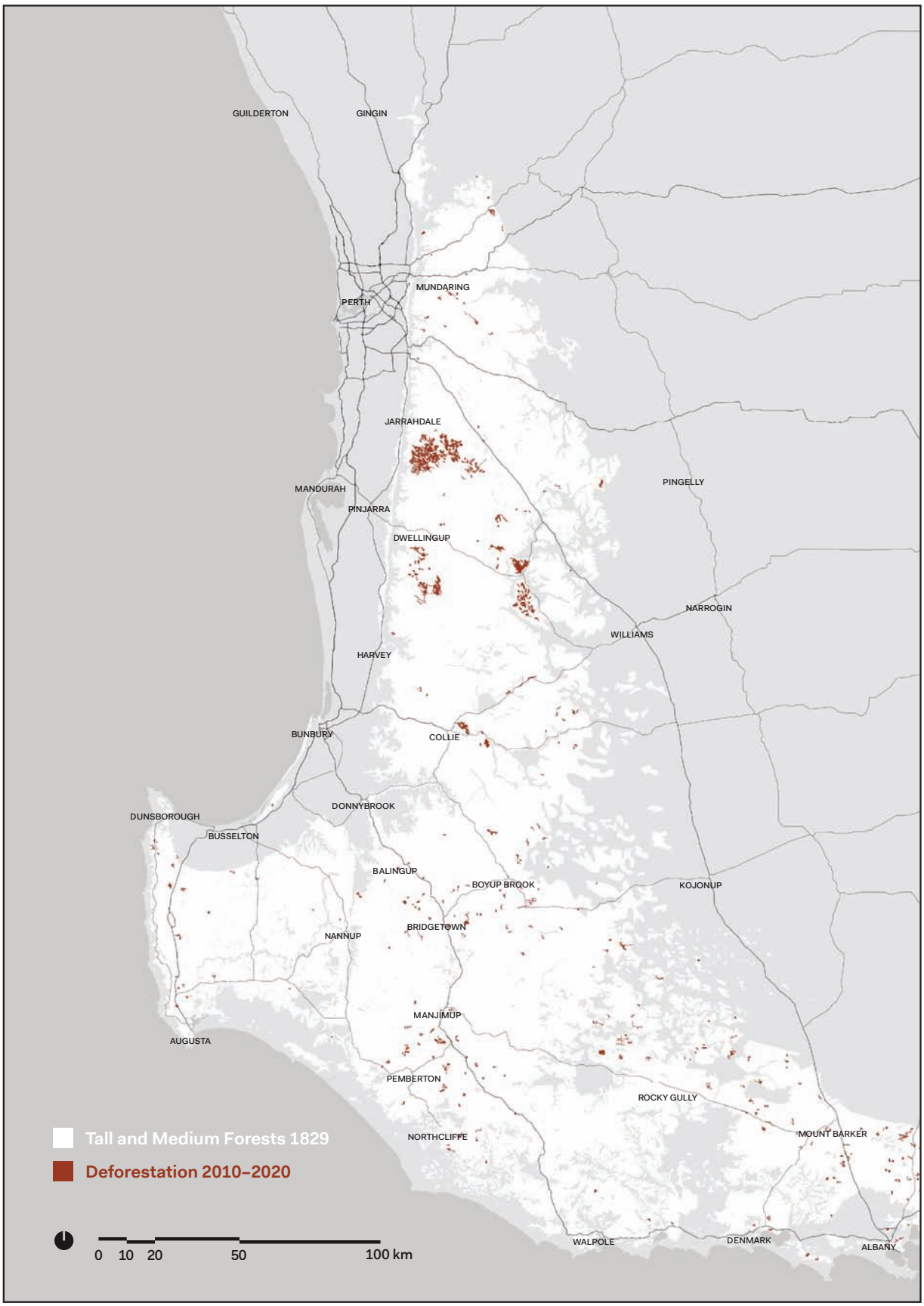
> From available data, we calculate 62.5% of all deforestation in WA's tall and medium forests between 2010 and 2020 was a result of bauxite mining.

Lack of records makes it impossible to calculate total deforestation and forest degradation in WA. It is disturbing that this information is not available, and particularly given the IPCC's findings that the Northern Jarrah Forest is at a high risk of collapse or transition under climate change, no further clearing of this unique and vulnerable ecosystem should be allowed.

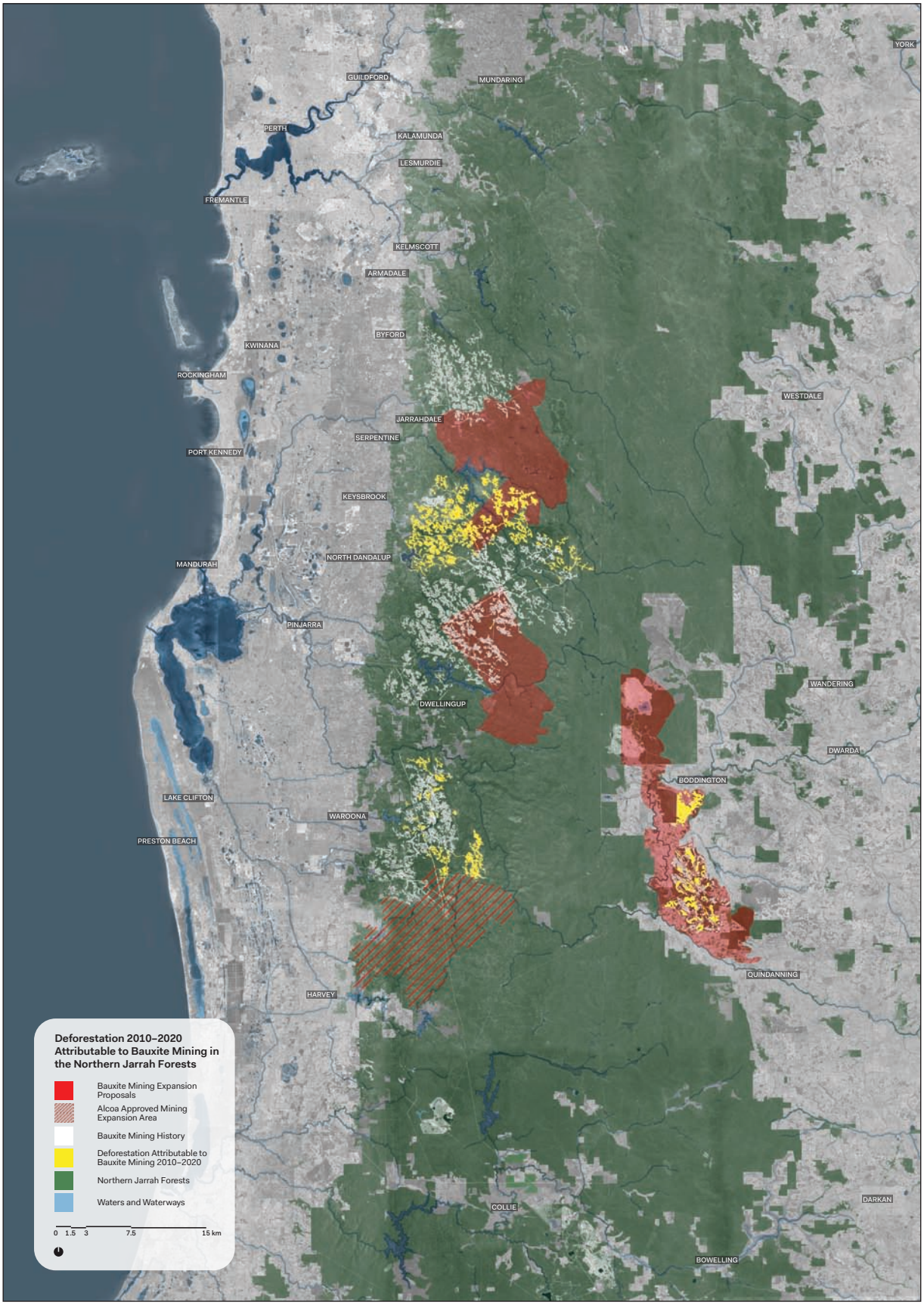
The minimal public records that are available for clearing of native vegetation reveal that between 2003/04 and 2019/20 clearing permits authorised clearing of 9,745 hectares in the Jarrah Forest and Warren IBRA bioregion (ie the Northern and Southern Jarrah Forests and the Karri and Tingle forests). By way of comparison, bauxite mining alone cleared 11,290 hectares of DBCA-managed land in the Northern Jarrah Forest between 2010 and 2020.

From available data, we calculate 62.5% of all deforestation in WA's tall and medium forests between 2010 and 2020 was a result of bauxite mining.

It has been estimated that in the long term up to 83,000 hectares will be cleared and 337,000 hectares fragmented for bauxite mining. Most of the forest between Collie and Armadale is expected to be fragmented by bauxite mining by 2060.



Map 3 – Deforestation 2010-2020



Map 4 – Deforestation 2010-2020 attributable to bauxite mining in the Northern Jarrah Forests

As discussed elsewhere in this paper, the IPCC's Sixth Assessment Report (2022) identifies the Northern Jarrah Forest as one of a handful of Australian ecosystems at specific risk of collapse or transition as a result of climate change. However, the report also finds that the risk can be substantially reduced by avoiding and reducing clearing and forest degradation from inappropriate forest management practices and land use.

Clearing of the Northern Jarrah Forest for bauxite mining

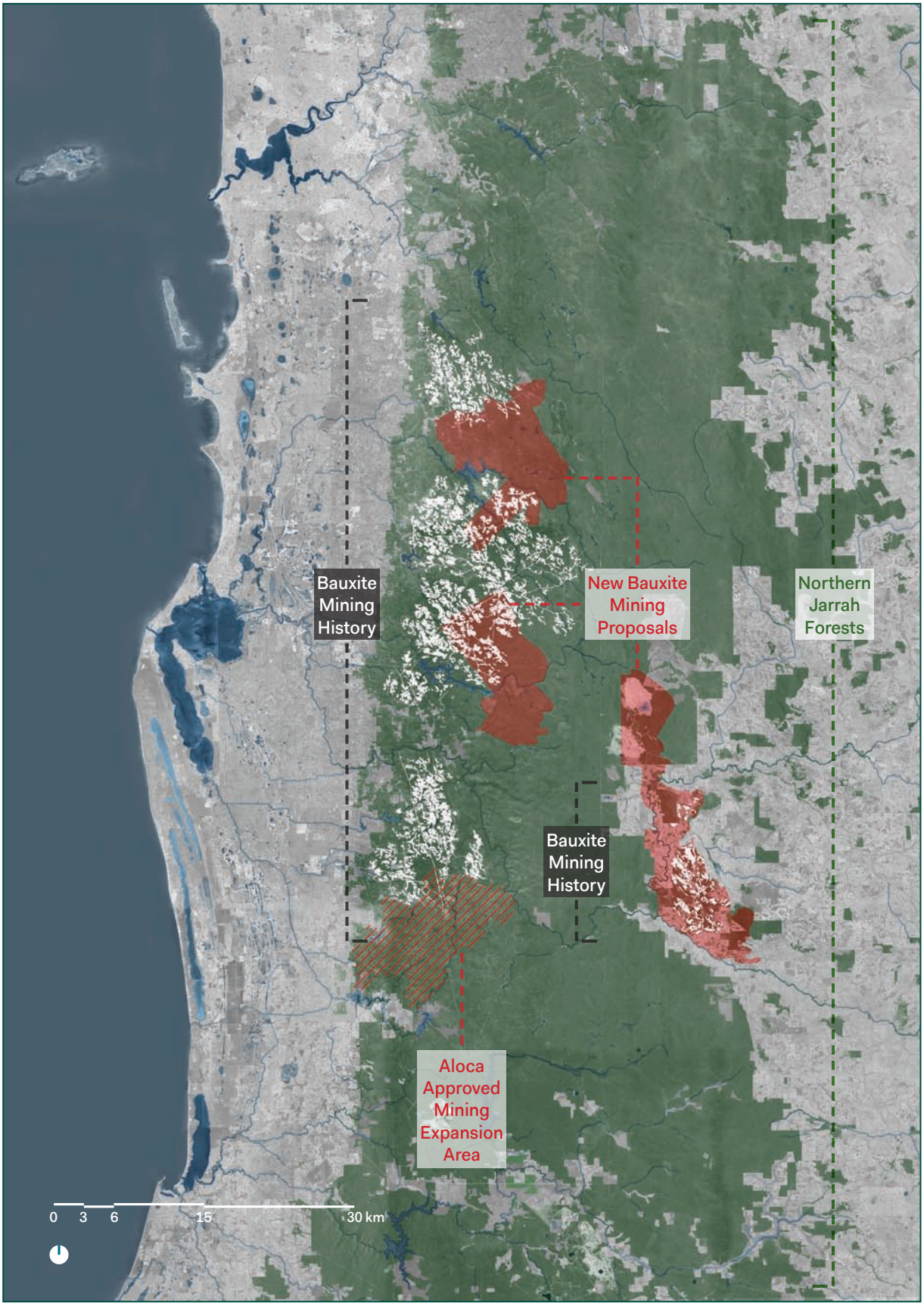
Bauxite mining has been happening in the Northern Jarrah Forest since the 1960s. The bauxite mining companies are Alcoa and South32 (Worsley).

See Map 5, Historic and proposed mining by Alcoa and South32, page 14.

When bauxite mining occurs, the merchantable trees are logged and sold as sawlogs, firewood and charcoal and the remaining vegetation and stumps are bulldozed into heaps and burned. Seed-containing topsoil and about 40 centimetres of the gravel beneath are scraped off and stored. The bauxite is mined, then metres of gravel are taken away creating a pit.

After mining, there is a process called rehabilitation. Bulldozers shatter the floor of the pit and landscape the surface. The stored gravel is spread on top, and the stored topsoil is spread on top of the gravel. The surface is then ripped for drainage and water movement and root penetration. The top 1.2 metres is shattered and surface ripples are created with mounds two metres apart. A mixture of seeds endemic to the locality is spread on the topsoil, and species that do not establish well from seed are planted as seedlings. Logs are placed to provide for future ground habitat. The area is fertilised in spring.[6]

Willowdale bauxite mine, March 2022. *Photo: Jess Beckerling*



Map 5 – Historic and proposed mining by Alcoa and South32

Willowdale bauxite mine, March 2022. *Photo: Jess Beckerling*

This video link shows a rehabilitated site in the Northern Jarrah Forest after 20 years:[7] https://www.youtube.com/watch?v=Y4VsZxwigDI. It is clearly not the same as the original forest.

As at December 2020, 32,130 hectares of land in the Northern Jarrah Forest managed by the Department of Biodiversity, Conservation and Attractions (DBCA) had been cleared for bauxite mining.[8] That is an area about 80 times the size of Kings Park.[9] The total area fragmented as at December 2019 was at least 92,000 hectares, nearly triple the amount cleared.[10] The DBCA's figures do not include any bauxite mining on private land. Alcoa's mineral lease includes private land[11] that has potentially mineable bauxite deposits.[12] In 2018 the Institute of Foresters of Australia said in total 120,000 hectares of the Northern Jarrah Forest had been impacted by bauxite mining, nearly quadruple the amount cleared.[13]

Clearing of native forest for other purposes

Clearing for bauxite mining is the main, but not the only, clearing for mining that happens in South West publicly owned native forest:

- The amount of DBCA-managed land cleared in the Northern Jarrah Forest by Newmont Boddington gold mine to December 2019 was 930 hectares[14]
- A 2018 DBCA overview of WA's forest management systems says that each year about 1,000 hectares of mostly State forests and timber reserves are subject to mining operations that include clearing, principally for extraction of bauxite, coal and gold.[15] The same year the Institute of Foresters of Australia said the annual rate of clearing for bauxite mining alone was 800 hectares.[16] As discussed below, that rate appears to be accelerating; in 2020 bauxite mining alone was responsible for clearing 870 hectares[17]

In addition to clearing for mining, about 7,500 hectares is currently impacted by native forest logging each year.[18]

South West native forest has also been cleared for grazing, agriculture and residential/urban development.

Lack of records about total native forest clearing, and the proportion by each sector

Working out how much in total of the South West's native forest is being cleared, and for what purpose, is impossible because there is no central record kept in Western Australia.

Instead of a central record and a consistent approach to the clearing of native vegetation, Western Australia has a 'legislative spaghetti' involving more than 10 government departments and authorities and 16 Acts that have widely varying primary goals.[19] This is even though:

- The Environmental Protection Agency has said that clearing of native vegetation is a key threat to WA's biodiversity[20]
- Habitat loss is the number one threat to biodiversity worldwide[21]
- Australia has one of the highest rates of species loss in the world[22]

In 2019, the WA government released a Native Vegetation in Western Australia Issues Paper for public consultation.[23] It conceded that WA needs a central record for native vegetation, saying:

- Western Australia's current data systems don't track what native vegetation we have, or its condition, or its type, or how it is being managed, or how much of it is getting cleared[24]
- There is a central record of clearing pursuant to clearing permits since 2004 but this is only 3% of historical clearing in the State to date.[25] Those records do not include:
  - Clearing approved under Part IV of the Environmental Protection Act 1986 (ie proposals that are likely to have a significant impact on the environment)[26]
  - Clearing authorised by other processes such as subdivision approvals under the Planning and Development Act 2005
  - Exempt clearing (i.e. clearing allowed under the Environmental Protection Act without any permit or approval)[27]
  - Illegal clearing[28]

The minimal public records that are available for deforestation reveal only that between 2003/04 and 2019/20 clearing permits authorised clearing of 9,745 hectares in the Jarrah Forest and Warren IBRA bioregions (i.e. the Northern and Southern Jarrah Forests and the Karri and Tingle forests).[29] Those records do not break down to show clearing by sector. However, by way of comparison, bauxite mining alone cleared 11,290 hectares of DBCA-managed land in the Northern Jarrah Forest between 2010 and 2020.[30]

There are some publicly available vegetation maps[31] but again they are imprecise in identifying how much each sector is clearing the forest. A project by the Koorabup Trust and Gondwana Link argues that current mapping is not fit for purpose and makes proposals for improvement.[32] This report uses remnant vegetation datasets maintained by the Department of Primary Industries and Resources to quantify the amount of tall and medium forest cleared between 2010 and 2020 using GIS software and analysis. This is the best data currently available in Western Australia but it is complex to navigate, and as stated above, it does not identify the causes of clearing.

The Australian government has, since 2010, kept a central record of land clearing - the National Greenhouse Gas Accounts. But once again those records are unhelpful in identifying the total amount of deforestation and the contribution of each sector to that. This is because the purpose of the National Greenhouse Gas Accounts is to measure greenhouse gas emissions, not biodiversity. The Accounts therefore omit important information about biodiversity and habitat loss.

Because of this, the Wentworth Group of Concerned Scientists is advocating for the creation of regularly updated maps of habitat loss across Australia to underpin policy and management decisions relating to biodiversity.[33]

A 2020 ABC article by Nick Kilvert[34] demonstrates that trying to use the National Greenhouse Gas Account figures to measure loss of native vegetation habitat leads to absurd conclusions, for example that despite clearing, tree cover is increasing. This is because:

- The figures measure net forest clearing, comparing the amount of land cleared with the amount of land regrown
- Woody vegetation gets included in the figures if it has a height or potential height of greater than 2 metres, crown cover greater than 20% and a minimum patch size of 0.2 hectares
- This means that clearing mature forest and planting an equivalent area with 2 metre saplings is not recorded as a loss in forest cover, despite the loss of habitat and carbon storage
- Similarly, thinning a dense forest is not recorded as a loss in forest cover unless the canopy is reduced to 20% or less. For example, the "before and after" images below were not recorded as a loss of forest cover:

Tree thinning shown between the image in 2015 (left) and 2016 (right) wasn't picked up in National Greenhouse Gas Accounts data.

Bearing in mind the issues with definitions and shortcomings of the data, the article says that the National Greenhouse Accounts show that 288,400 hectares were cleared in Western Australia between 2010 and 2018, 68,700 of it in primary forests ('primary' means forests at least 30 years old).[35] By way of comparison again, bauxite mining cleared 11,290 hectares of DBCA-managed land in the Northern Jarrah Forest between 2010 and 2020.[36]

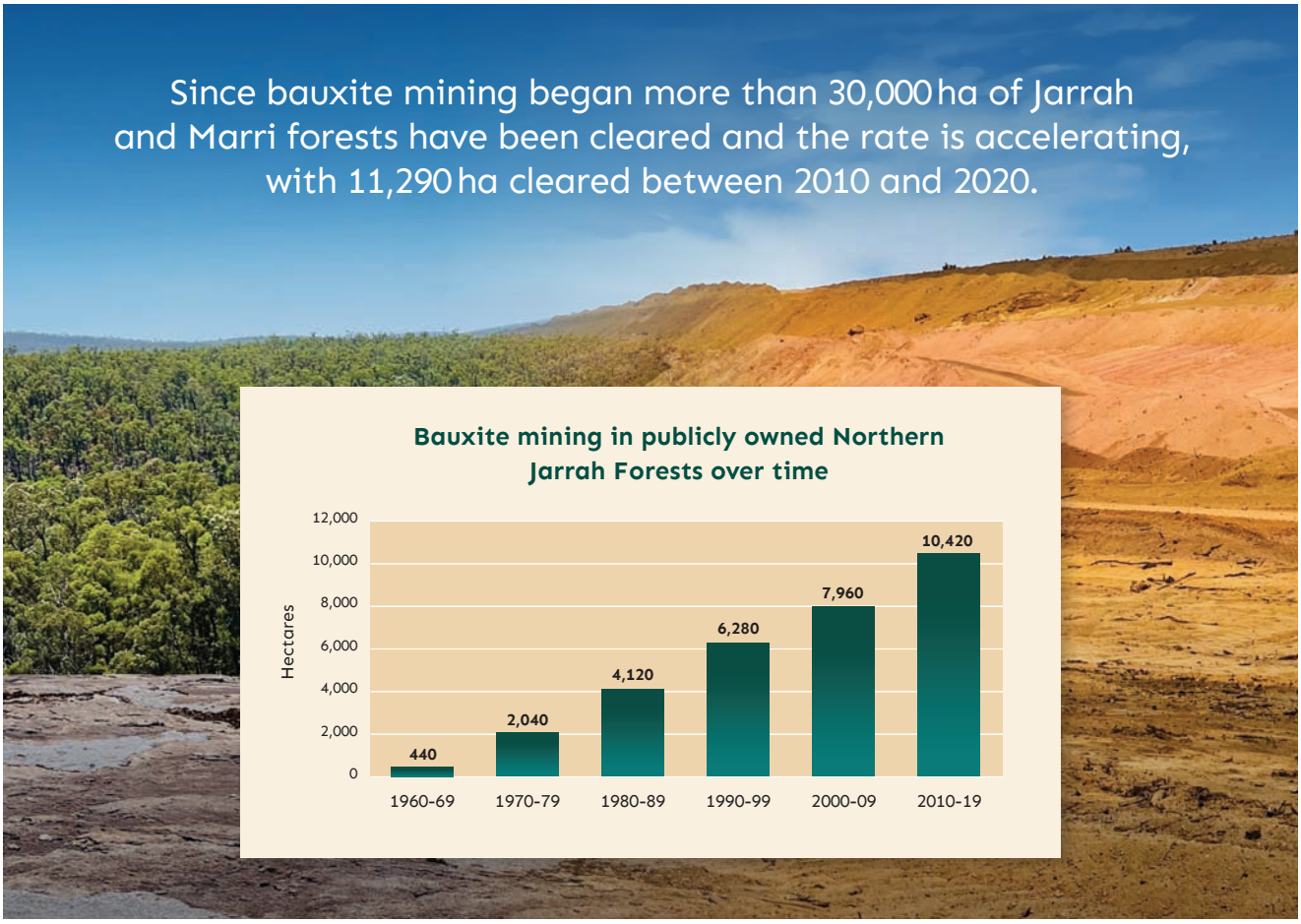
Boddington bauxite mine, March 2022. *Photo: Jess Beckerling*

Acceleration of clearing in the Northern Jarrah Forest for bauxite mining

The rate of clearing of DBCA-managed land in the Northern Jarrah Forest by bauxite mining companies has accelerated:[37]

- 1960-1969: 440 hectares
- 1970-1979: 2,040 hectares
- 1980-1989: 4,120 hectares
- 1990-1999: 6,280 hectares
- 2000-2009: 7,960 hectares
- 2010-2019: 10,420 hectares
- 2020: 870 hectares

That is, over a third of the total six decades' clearing occurred between 2010 and 2020 alone.



The volume of Jarrah sawlogs extracted before mining (including for bauxite and mineral sands) over the last five years confirms recent acceleration in mining activity:[38]

- 2016: 15,695 cubic metres
- 2017: 8,552 cubic metres
- 2018: 8,522 cubic metres
- 2019: 5,646 cubic metres
- 2020: 10,268 cubic metres

Jarrah logs being transported to mill. *Photo: Ray Swarts*

Alcoa and South32 are both currently seeking approval to increase the amount of clearing they can do by another 11,109 hectares:

- Alcoa is seeking approval to clear up to 6,700 hectares of native vegetation and fauna habitat within a 42,415 hectare development envelope associated with mining, and an additional 10 hectares of native vegetation associated with the refinery[39]
- South32 is seeking approval to clear up to 4,399 hectares of native vegetation for its mine and mining related activities within a 27,796 hectare mining development envelope[40]

Together, the two proposals seek authorisation to clear over a third as much again as was cleared for bauxite mining between 1960 and 2020. The development envelope is three quarters as much again as the area fragmented to December 2019.

How much more native forest could be cleared for bauxite mining in the future? Alcoa's mineral lease ML 1SA is 712,881 hectares across private land holdings, state forests, national parks and conservation areas in the Darling Range and from east of Perth to east of Bunbury.[41] The term of the lease is to 2024 and renewable to 2045.[42] Alcoa's 2020 annual report says[43] that as of 31 December 2020 its Huntly and Willowdale mines had 95.8 million dry metric tonnes of probable bauxite reserves[44] and 43.2 million dry metric tonnes of proven bauxite reserves.[45] 'Reserves' are not the total bauxite resources available.[46] It is not cost effective for Alcoa to establish reserves that reflect the total size of the bauxite resources available to it.[47] Instead some resources are upgraded annually to reserves after additional exploration and development drilling has revealed their physical and chemical characteristics and limits.[48] According to a 1992 Department of Mines report, the Darling Range has hundreds of potentially mineable bauxite deposits, although development of some of them may be constrained to some extent because they are co-located with conservation parks and reserves, water catchment areas and private land.[49] However, bauxite mining does occur in water catchment areas and there is other clearing in conservation reserves. There is no publicly available information on what limits government authorities actually place on bauxite mining in water catchments.

Alcoa says it has in the past relinquished 15% of its bauxite reserves for biodiversity purposes,[50] that to date it has cleared less than 4% of its lease, and that it currently expects to clear less than 8%.[51] However:

- That is double the amount cleared by Alcoa to date – a vast area of highly valuable and vulnerable forest
- It does not include the habitat area that will be fragmented by the clearing. As indicated above, the area fragmented to December 2019 was at least triple and possibly quadruple the area cleared
- As indicated above, Alcoa's very large lease area covers hundreds of potentially mineable bauxite deposits and each year some of those deposits get upgraded to reserve status

Reference material for Jarrah forest silviculture produced by the Department of Parks and Wildlife in 2015 said:

- 45% of State forest and timber reserves were currently under bauxite mining leases
- Another 37% were under pending mining leases
- It was estimated that 83,000 hectares may be cleared in the long term, fragmenting about 337,000 hectares of the Jarrah forest, mostly in the Northern Jarrah Forest[52]

In 2018, the Institute of Foresters of Australia similarly said that bauxite mining is likely to have a direct impact on over 80,000 hectares of the Northern Jarrah Forest and an overall impact on over 300,000 hectares – and explained that this means most of the forest between Collie and Armadale is expected to be fragmented by bauxite mining by 2060.[53]

BAUXITE MINING THREATENS MAINLAND QUOKKAS (SETONIX BRACHYURUS)

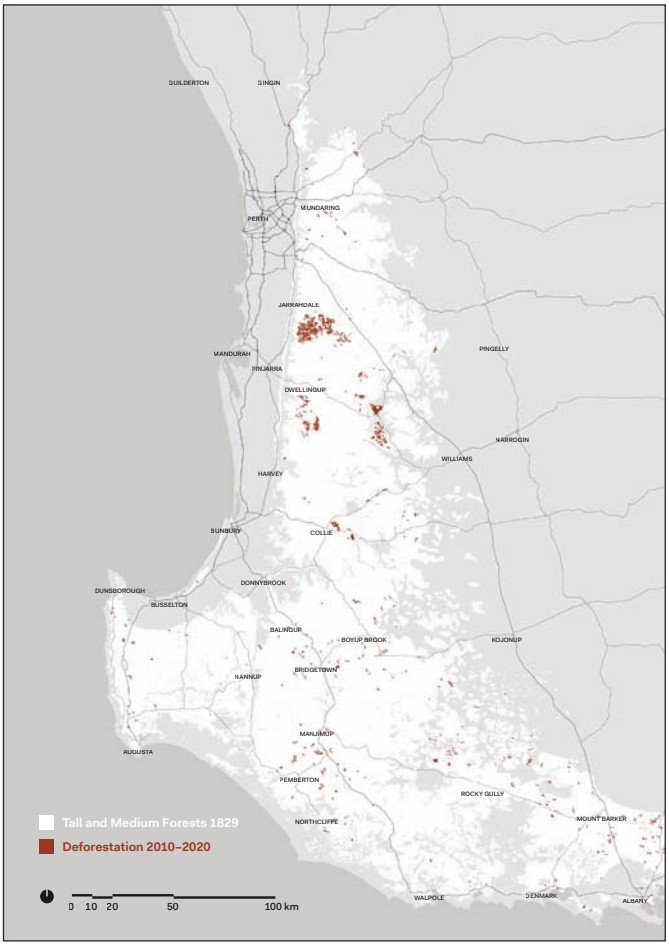
Mainland Quokka. *Photo: Philippa Beckerling*

KEY POINTS:

Bauxite mining is the primary cause of clearing of forest habitat in the mainland Quokka's Northern Jarrah Forest sub-population.

Quokkas in the Northern Jarrah Forest, including in the areas proposed to be cleared by bauxite miners Alcoa and South32, are extremely vulnerable because they are a threatened species. They have a very particular habitat, are vulnerable to predators (especially foxes) outside that habitat, are impacted by fragmentation of their habitat, are few in number, and are losing resilience and the ability to recover from disturbance.

There are estimated to be as few as 150 individuals remaining in the Northern Jarrah Forest sub-population of Quokkas.



Left: General sub-populations of Quokkas in South West of WA (DEC 2013)[54] Right: Deforestation 2010-2020

There are Mainland Quokkas living in the Northern Jarrah Forest.

The areas proposed to be cleared by both Alcoa and South32 in the Northern Jarrah Forest include (Alcoa) or are highly likely to include (South32) Quokkas and/or Quokka habitat.[55]

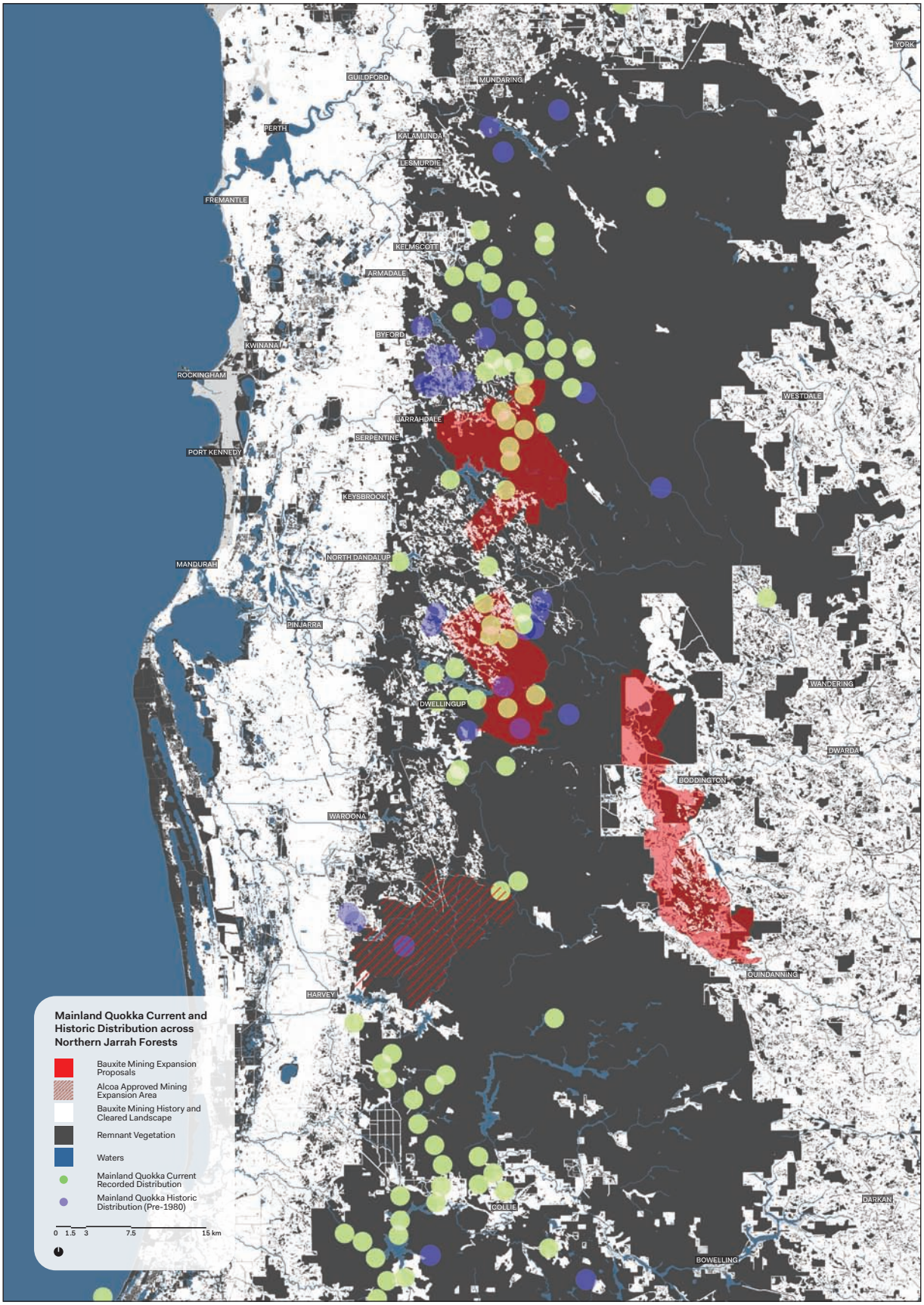
Bauxite mining that previously occurred near a Quokka colony at Wild Pig Swamp in the Northern Jarrah Forest may have contributed to the decline of that colony.[56] In 2007 the local population of Quokkas at Wild Pig Swamp was presumed locally extinct.[57]

Quokkas once thrived in the South West of Western Australia, where pre-European conditions were ideal for their survival.[58] Female Quokkas can produce 1.8–2.0 young per year and 17 young over a lifetime.[59] Yet Quokkas are now a threatened species with a status of 'vulnerable' under State[60] and Commonwealth law.[61]

The Northern Jarrah Forest Quokka population in particular is small and declining.[62] They are generally restricted to colonies of no more than 30 individuals[63] living in small and scattered habitat patches of around 6[64] or 7[65] hectares in swamps and riparian areas. The total adult population in the Northern and Central Jarrah Forest may be as few as 150.[66]

The most significant reasons for their decline are predation (especially by foxes) and loss/alteration of habitat.[67]

The Quokka's habitat is a complex mosaic that simultaneously provides enough fresh water to meet their high water needs, enough low regrowth vegetation to provide food (found in areas that have recently been burnt), and enough dense understorey thicket to protect them from predators as the Quokkas move about (found in areas that haven't been burnt for a long time).[68]



Map 6 – Mainland Quokka current and historic distribution across Northern Jarrah Forests

Willowdale bauxite mine, March 2022. *Photo: Jess Beckerling*

Such areas are dynamic, with wet areas expanding and shrinking with the seasons, and forage vegetation eventually growing too high to reach, less species rich, and more open. Historically Quokkas abandoned their patch when it became unsuitable and moved on to colonise a new one.[69] But now much of their habitat is lost or fragmented and moving through the open forest to a new patch makes Quokkas vulnerable to predators.

These limitations on their ability to move to new habitat patches is causing Northern Jarrah Forest Quokka populations to become geographically and genetically isolated, and unable to recover from disturbance or adapt to changing habitat conditions.[70]

Bauxite mining is the primary cause of habitat clearing in the Northern Jarrah Forest, in the habitat range of the Northern Jarrah sub-population of Quokkas. It contributes to the temporary loss and longer term alteration of Quokka habitat, opening up access by predators by clearing and fragmenting the forest[71] and by changing surface water drainage patterns[72]. It can also introduce dieback into Quokka habitat causing damage to forest structure.[73]

In addition, the decline of the Wild Pig Swamp Quokka colony in the Northern Jarrah Forest may have been related to noise disturbance and roadkill from bauxite mining within 20 metres of the swamp.[74]

Translocation of Quokkas from elsewhere (for example Rottnest) to the Northern Jarrah Forest has been considered but concerns have been raised about the genetic and species management implications of this.[75] The Quokka Recovery Plan proposes the need for translocation be evaluated.[76] As of 2020, translocation was still under consideration by the Quokka Recovery Team.[77]

There are big gaps in our knowledge about mainland Quokkas. Decisions about them and their habitat are made based on short term studies and anecdotal material instead of robust and reliable information.[78] The Quokka Recovery Plan and a 2020 report by Amy Marsden both highlight the knowledge gap and make recommendations for research to improve our ability to protect threatened Quokkas and their habitat.[79]

BAUXITE MINING THREATENS THREE SPECIES OF BLACK COCKATOO

KEY POINTS:

Three threatened species of black cockatoo live in the Northern Jarrah Forest, including in the areas proposed to be cleared by bauxite miners Alcoa and South32.

Bauxite mining is the primary cause of deforestation in habitat for all three species of South West black cockatoos.

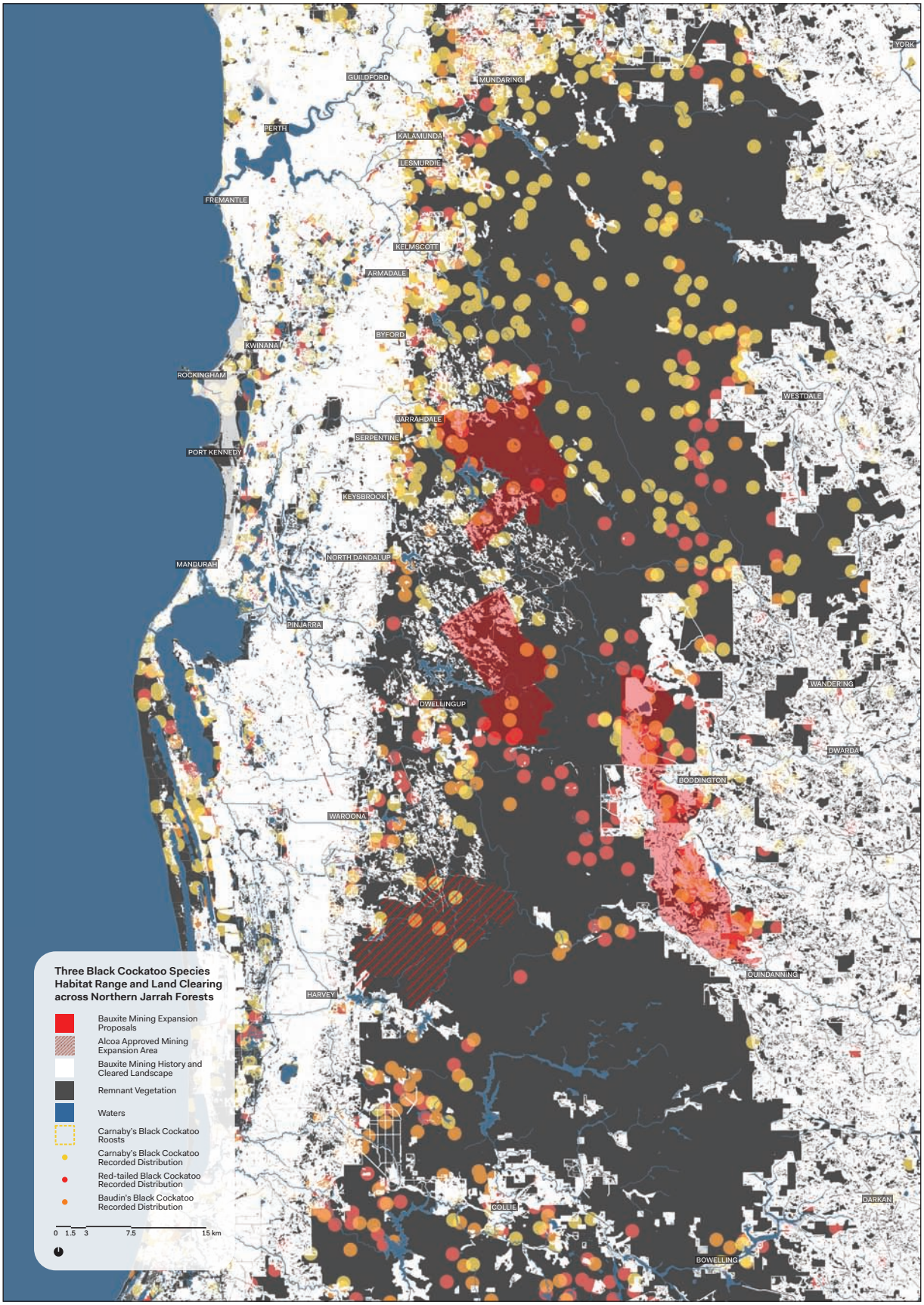
The numbers of all three threatened species are declining and the main reason is habitat loss and fragmentation. Their Recovery Plans refer specifically to mining as a contributor to this and call for identification, protection and enhancement of habitat critical to their survival *(Carnaby's Cockatoo Recovery Plan)* and determination and implementation of ways to minimise the effects of mining and urban development on habitat loss *(Forest Black Cockatoo Recovery Plan)* but these recommendations have not been implemented.

There is no robust evidence that more habitat can be lost without significant adverse impacts.

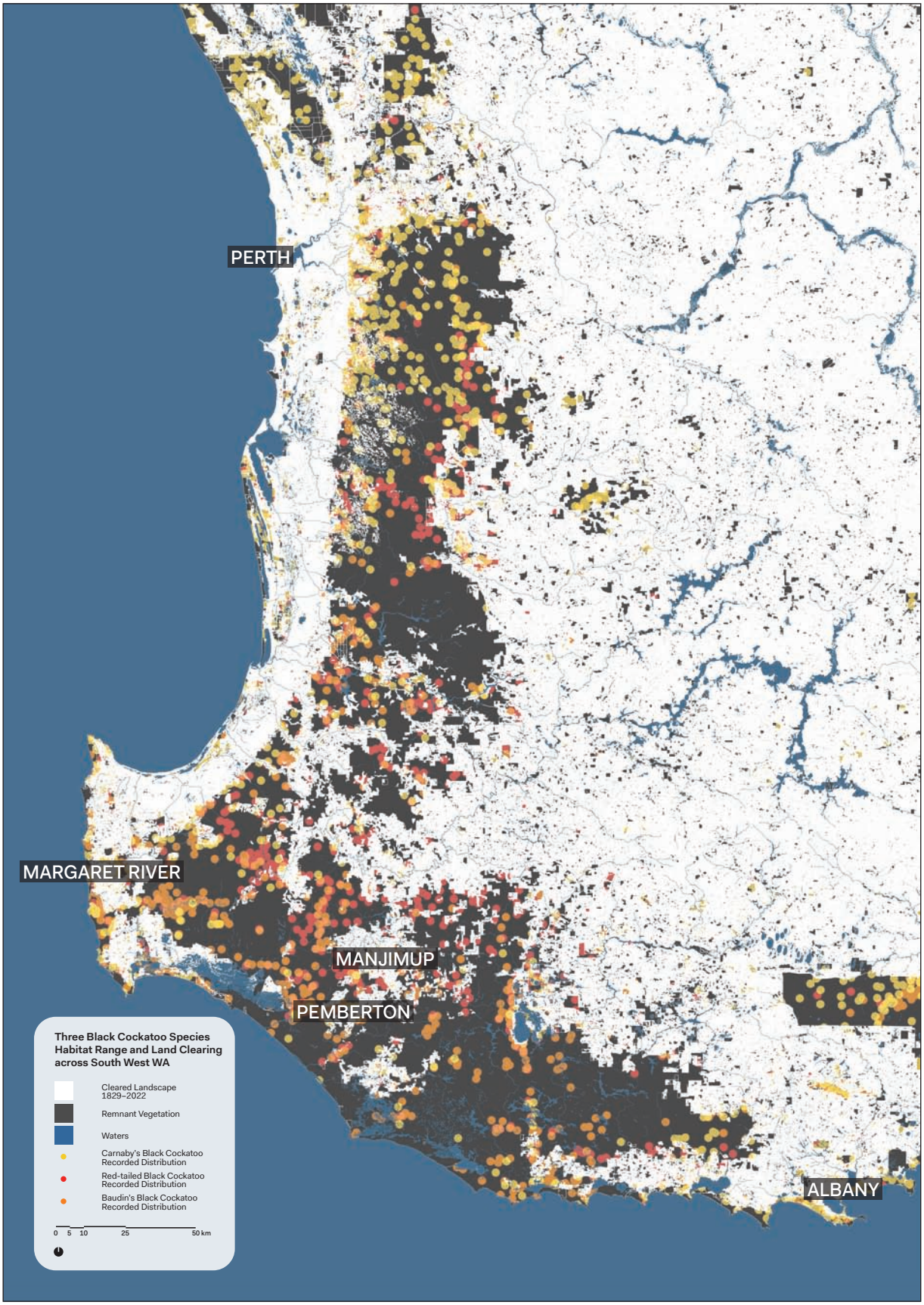
All three species breed in hollows of native trees at least a century old. Clearing for bauxite mining removes these trees and no rehabilitated site has native trees anywhere near that old. As noted elsewhere in this paper, putting nest boxes at all rehabilitated sites for fauna is considered impractical.

Although rehabilitated mine sites provide some food resources from four years on there is no evidence that this provides equivalent food resources to the original forest that was cleared. Jarrah and especially Marri are important food resources.

Forest red-tailed black cockatoo.
Photo: Kerem Kanadikirik (Kero) Insta: what_kero_seen



Map 7 – Three black cockatoo species habitat range and land clearing across Northern Jarrah Forests



Map 8 – Three black cockatoo species habitat range and land clearing across South West WA

Three species of Western Australian black cockatoo live in the Northern Jarrah Forest. All of them are listed as threatened species under both State and Commonwealth legislation. The total WA population of Carnaby's cockatoo is estimated at 40,000, that of Baudin's cockatoo is estimated at 12,000 and that of Forest red-tailed black cockatoo is estimated at 15,000.[80] The population of all three species is declining.[81]

Alcoa's environmental referral supporting document says:

- Carnaby's cockatoo or their habitat is known to occur within the proposed development envelope
- Baudin's cockatoo roosting is known to occur within the proposal development envelope
- Forest red-tailed black cockatoo or their habitat is known to occur within the proposed development envelope[82]

The material provided by South32 in support of its application for approval to clear more native vegetation says all three threatened species have been recorded in the areas to which the application relates and are highly likely to be present.[83]

Carnaby's black cockatoo. *Photo: Donna Chapman*

Carnaby's cockatoo *(Calyptorhynchus latirostris)*

The once numerous Carnaby's cockatoo is now an endangered species,[84] its decline primarily attributable to loss and fragmentation of its habitat through clearing of native vegetation amounting to approximately 56% or 2 million hectares since European colonisation.[85]

Carnaby's black cockatoo. *Photo: Philippa Beckerling*

Carnaby's cockatoo are generally semi-migratory, spending their breeding season inland and their non-breeding season in higher rainfall coastal areas.[86]

The Great Cocky Count is an annual count by citizen scientists of black cockatoos as they come to roost for the night. As of the date of writing, the most recent report was from 2019.[87] 2019 was the tenth time the count had been conducted.[88] The count was cancelled in 2020 because of the Covid 19 pandemic. The count resumed in 2021 but as at the date of writing the report for the 2021 count had not yet been published.[89]

The 2019 report of the Great Cocky Count indicates that in the Northern Darling Scarp and Plateau (which encompasses the Jarrah-Marri Forest and Darling Plateau from north of Bindoon to south of Boddington) Carnaby's cockatoo is present at low densities throughout the forest and has significant roosts in the forest north of Mundaring.[90] The southern and eastern parts of the Northern Darling Scarp and Plateau appear to be under-surveyed as there is anecdotal evidence of some roosts that are not yet contained in the database.[91]

The report estimates that the population of Carnaby's cockatoo and Baudin's cockatoo combined[92] in the Northern Darling Scarp and Plateau is declining at a rate of 13% annually.[93] It is not known whether the decline is because of loss of birds (for example adult bird mortality, reduced survival of juveniles, or reduced breeding effort or success) or because the birds have moved (out of the area, or to new roost sites within the area) or both.[94]

Carnaby's black cockatoos using nest hollow. *Photo: Philippa Beckerling*

Carnaby's cockatoo habitat includes:

- Live or dead eucalypts with nest hollows for breeding season. It takes at least 100-200 years for eucalypts to grow large enough to provide nest hollows for Carnaby's cockatoo.[95] There can be competition for nest hollows with other species like the European honey bee, galahs and corellas[96]
- Night time roosting sites for non-breeding season
- Foraging sites at both locations:
  - Breeding success depends on the quality and proximity of feeding habitat to nesting sites.[97] Extra time and energy spent flying further for food means that less food is delivered to chicks, especially when daytime temperatures are higher, so the chicks can die or have developmental impairments that can cause death[98]
  - Carnaby's cockatoo are opportunistic feeders and have expanded their diet of mainly native seeds and nectar to include seeds from introduced canola and plantation pine[99] and fruit and nut crops. Because of this they are sometimes illegally shot by crop owners, or die by poisoning.[100] It is also not clear how many exotic foods compare with native foods in terms of energy value in exchange for effort expended[101]
- Access to water at both locations.

There is no robust information identifying that further habitat can be lost without significant adverse impact on the population of Carnaby's cockatoo.[102] It is known that breeding sites must not be lost.[103] Most habitat that provides for feeding, regular roosting and potential for breeding is considered important.[104] Identified breeding and nearby feeding habitat, former breeding habitat with intact hollows, and vegetation providing habitat for feeding, watering and regular night roosting is considered critical for the recovery of Carnaby's cockatoo.[105]

The Carnaby's Cockatoo Recovery Plan therefore stresses the need to protect and regenerate existing breeding and non-breeding habitat.[106] This includes preventing further clearing of habitat.[107]

The Carnaby's Cockatoo Recovery Plan specifically considers clearing associated with mining/ extraction, including bauxite mining in the Jarrah Forest, and states that in some areas this could affect the survival of the species:[108]

- Rehabilitation of foraging habitat has a high risk of failure. If successful it can (depending on the species and quality of establishment) begin producing food resources in eight years, but not necessarily to the same food value as the original vegetation. In addition, rehabilitation of foraging habitat, while considered achievable, has not yet been demonstrated at scale[109]

- Any loss of breeding trees/habitat is effectively permanent regardless of rehabilitation because it takes at least 100-200 years for eucalypts to develop nest hollows large enough for Carnaby's cockatoo. As noted elsewhere in this paper, rehabilitated mine sites did not use endemic trees until 1988 so it will be at least 2088 before nest hollows are available, and it is considered impractical to routinely include nest boxes for fauna at rehabilitated mine sites[110]

The Carnaby's Cockatoo Recovery Plan also identifies climate change as a threat to Carnaby's cockatoo:[111]

- Reduced rainfall is likely to significantly affect the extent and survival, or capacity to regenerate, of vegetation in their breeding or non-breeding habitat
- Changes to fire and rainfall may adversely impact the successful regeneration of the eucalypt species that provide nest hollows
- Timing and frequency of flowering and the amount of seed produced may be affected by climate change
- Unpredictable and extreme weather events – which are predicted to become more frequent as the climate changes - can significantly change local population dynamics, including breeding birds. For example in January 2010 over 200 Carnaby's cockatoo died from heat stress at Hopetoun and Munglinup and in March 2010 36 Carnaby's cockatoo were reported to have died and 20 were injured by a severe hail storm in Perth. In 2010/11 tree collapse as a result of heatwave and drought was followed by a 34% decline in the population of Carnaby's cockatoo in the Greater Perth Region[112]

Doubts have been raised about the efficacy of the *Carnaby's Cockatoo Recovery Plan* and indeed of recovery plans generally. On 20 October 2021, questions asked of the Department of Biodiversity, Conservation and Attractions during the WA Parliament's budget estimates revealed that recovery plans are not specifically allocated resources for their implementation and that the key performance indicator is the number of critically endangered and endangered taxa and ecological communities that have a recovery plan, not the level of progress that is being made through implementing recovery plans.[113]

Photo: Philippa Beckerling

Baudin's cockatoo *(Calyptorhynchus baudinii)* and Forest red-tailed Black Cockatoo *(Calyptorhynchus banksii naso)*

Like Carnaby's cockatoo, Baudin's cockatoos are generally semi-migratory, but in a different direction. Baudin's cockatoo breed mostly in the lower South West Karri and Jarrah-Marri forests, then fly north to the Darling Range.[114]

The distribution and total population size of Baudin's cockatoo has declined greatly in the last 50 years, with counts declining by over 90% since 2009.[115]

Forest red-tailed black cockatoos traditionally spend their lives near where they hatched.[116] They inhabit vegetation that is fairly continuous and are most common in the Jarrah forest region of the northern Darling Range between Collie and Mundaring and are very local throughout the lower South West.[117] However, since 2005 a small percentage of the population[118] has been visiting the Swan Coastal Plain seasonally to feed on Perth's exotic Cape Lilac trees.[119]

The report of the 2019 Great Cocky Count indicates an increase of Forest red-tailed black cockatoo in the Northern Darling Scarp and Plateau of 10% per year.[120] However since the birds are very slow breeders and there has been a significant decline in their breeding success in the Northern Jarrah Forest, that increase is most likely not because there are more of them but because some of them are now moving seasonally.[121]

Baudin's cockatoo and Forest red-tailed black cockatoo are both threatened species. The status of Baudin's cockatoo is endangered under Western Australian legislation[122] and Commonwealth legislation.[123] The status of Forest red-tailed black cockatoo is vulnerable under Western Australian legislation[124] and Commonwealth legislation.[125] The two species have a combined Forest Black Cockatoo Recovery Plan because of the similarity in their breeding and feeding needs and the threats they face.[126]

As with Carnaby's cockatoo, the main cause of both species' decline is habitat loss.[127] Nesting hollows are scarce as trees with hollows large enough for the cockatoo may be between 200 and 500 years old[128] and there is competition for hollows with wood ducks, galahs, corellas, feral honey bees[129] and Regent parrot[130] - and also amongst the three threatened black cockatoo species themselves.[131]

Baudin's cockatoo nests in Marri, Karri, Jarrah and Wandoo hollows, and feeds mainly on Marri seeds and flowers, but also on the seeds of various native species including Banksia, Hakea, Dryandra and Jarrah, insect larvae, and apple and pear seeds in orchards.[132] The latter can result in them being illegally shot by fruit growers[133] and the Recovery Plan contains actions aimed at reducing orchard damage and illegal shooting of the birds.

Banksia prionotes. Photo: Donna Chapman

Photo: Jess Beckerling

"Nesting hollows are scarce as trees with hollows large enough for the cockatoo may be between 200 and 500 years old and there is competition for hollows with wood ducks, galahs, corellas, feral honey bees and Regent parrot - and also amongst the three threatened black cockatoo species themselves."

Forest red-tailed black cockatoo nest in Marri, Jarrah and Karri hollows and may only breed when Marri fruit is abundant.[134] Their main diet is Marri and Jarrah seeds, but they also feed on other species.[135] The migration of some of them to feed on Cape Lilac may be opportunism or it may reflect a decline in the availability or nature of Jarrah and Marri as food.[136] Decline in water availability on the Darling Scarp because of the drying of seasonal and permanent streams may also be contributing to the birds expanding their range to Perth.[137] As noted elsewhere in this paper, in addition to declining rainfall, areas rehabilitated by bauxite miners reduce streamflow.

Black cockatoos in Dwellingup forest. *Photo: Jess Beckerling*

The *Forest Black Cockatoo Recovery Plan* identifies the habitat critical to survival and important populations of both cockatoo species as all Marri *(Corymbia calophylla)*, Karri *(Eucalyptus diversicolor)* and Jarrah *(Eucalyptus marginata)* forests, woodlands and remnants in the South West of Western Australia receiving more than 600 mm of annual average rainfall.[138]

Like the Carnaby's Cockatoo Recovery Plan, the Forest Black Cockatoo Recovery Plan specifically considers clearing associated with mining, including bauxite mining. Action 14.7 is to determine and implement ways to minimise the effects of mining and urban development on habitat loss, with known feeding, breeding and roosting habitats to be retained wherever possible. Despite this, the 2020 annual report of the Forest Black Cockatoos Recovery Team (the most recent annual report we could access) said:

- "No further progress. Expansion of two major bauxite mines in the southern portions of the Northern Jarrah Forest between Dwellingup and Collie, the lithium mine at Greenbushes and gold mine at Boddington will result in the estimated clearing of at least 10,000 Ha of Baudins [sic] and Forest Red-tail Black Cockatoo habitat over the next 10 years"[139]
- "Concern over the significant expansion of two major bauxite mines in the southern portions of the Northern Jarrah Forest and the loss of nesting, roosting and feeding habitat for all 3 cockatoo species. The team is unaware of any discussions with the companies re: type and scale of offsets proposed"[140]

Climate change is also identified in the Forest Black Cockatoo Recovery Plan as a threat affecting the entire populations of both species through changes to biodiversity and ecosystem function.[141]

Use of rehabilitated mine sites by the three threatened species of black cockatoo

As indicated elsewhere in this paper, rehabilitated mine sites will not provide tree nest hollows for breeding by any of the three threatened black cockatoo species until at least 2088, nor do they routinely provide nest boxes for fauna as this is considered impractical.

We found two studies that investigate how the three black cockatoo species use rehabilitated mine sites.

A 2013 paper *Ecology of Black Cockatoos at a Mine-site in the Eastern Jarrah-Marri Forest, Western Australia* by Jessica Lee, Hugh Finn and MC Calver reported on a three year study at the Newmont Boddington Gold Mine and its surrounds.[142] It found that the three species differ in their use of rehabilitated mine sites.

Baudin's cockatoo mainly occurred in unmined/intact forest but also used mine site rehabilitated vegetation.[143] Marri was their main food source[144] therefore retaining or restoring Marri was considered critical for Baudin's cockatoo.[145]

Carnaby's cockatoo fed on the broadest range of plants[146] and used the broadest range of habitat types including mine site rehabilitation (where they fed on proteaceous shrubs) and pine plantation.[147] They fed on at least 10 species with no plant accounting for more than 20% of feeding observations.[148] Jarrah was an important food source.[149]

(NB: Regarding the observation that Carnaby's cockatoo fed on proteaceous shrubs in mine site rehabilitation, Proteaceae species are one of the most common families of flora in unmined/intact Jarrah forest[150] but are less common at rehabilitated mine sites because they can harbour the dieback pathogen and are therefore reduced in the seed mixes used by mining companies).[151]

Forest red-tailed black cockatoo used unmined/intact forest, and they also used farm paddocks for feeding and drinking.[152] Of the three species, Forest red-tailed black cockatoo have the highest basal metabolic rate and evaporative water loss, so it was thought that their distribution may be more determined by water availability than that of the other species.[153] This is significant given that rehabilitated mine sites reduce streamflow, as noted elsewhere in this paper.

Forest red-tailed black cockatoo.
Photo: Philippa Beckerling

Forest red-tailed black cockatoo fed mainly on Marri and Jarrah.[154]

They were not observed in mine site rehabilitation, although feeding residues there indicated some feeding activity.[155] This was consistent with earlier studies indicating infrequent use of rehabilitated areas less than 20 years old, even with Marri food resources present.[156]

Forest red-tailed black cockatoo were resident year round, but their distribution shifted periodically, probably based on availability of food (flowering and fruiting of Marri and Jarrah, followed by intensive feeding and depletion) and water.[157] No seasonal migration was observed.[158]

The study indicated that Forest red-tailed black cockatoos are the most vulnerable of the three black cockatoo species to disturbance from mining because their numbers are small, they tend to live year round in defined areas, and they feed infrequently from young mine site rehabilitation.[159] Their breeding is therefore best supported by in situ conservation of native vegetation.[160]

A second study in 2016 compared that research with feeding activity by the three species in rehabilitated areas at Alcoa's Huntly bauxite mine and South32's Boddington bauxite mine.[161] The age of those sites ranged from 4 to 23 years. The report mostly does not distinguish between the three cockatoo species. It found:

- At the rehabilitated mine sites cockatoos ate from proteaceous species (e.g. Banksia, Hakea) and myrtaceous species (e.g. Jarrah, Marri)
- Feeding on proteaceous shrubs started after four years and decreased as the myrtaceous species grew and the proteaceous shrubs became more sparse
- The cockatoos fed less on Jarrah and Marri at the rehabilitated mine sites than in intact forest, despite availability of Jarrah and Marri food resources at the rehabilitated mine sites from seven years onwards. This may have been because of differences in frequency of flowering and fruiting, or amount of fruit produced, or fruit quality
- More frequent feeding from young revegetation may have been because a more open forest structure gave better access
- Rehabilitated mine sites need to contain an appropriate proportion and number of Marri, and to a lesser extent Jarrah, for feeding habitat
- Equivalence of food resources between rehabilitated mine sites and intact forest was not established
- Cockatoo were not observed roosting at the rehabilitated mine sites
- The rehabilitated mine sites did not have nesting hollows

THE REGION NEEDS INTACT FORESTS FOR ITS CLIMATE RESILIENCE

KEY POINTS:

Forests remove carbon from the atmosphere, decrease temperature, reduce rainfall decline and provide fauna habitat.

Intact forests outperform rehabilitated mine sites.

Forest clearing is a major source of carbon emissions.

Rehabilitated mine sites use up to twice as much water as intact forests, transpiring ground water into the atmosphere and reducing water availability for surrounding forest ecosystems.

In 2018 the Institute of Foresters of Australia calculated, using research data from Alcoa, that the amount of water being lost to rehabilitated mine sites instead of going to adjacent intact forest and streams was 500,000 litres per hectare or 60 billion litres overall – more than the annual production of water by the Kwinana desalination plant.[162]

> Rainfall in South West WA has declined by about 20% since the 1970s, and that decline is projected to continue.

The Northern Jarrah Forest is a multiuse forest under enormous cumulative pressure from multiple sources including logging, clearing, and fire.

Willowdale bauxite mine, March 2022. *Photo: Jess Beckerling*

Photo: Jinni Wilson

Climate change is increasingly adding to that cumulative pressure. Rainfall in South West WA has declined by about 20% since the 1970s, and that decline is projected to continue.[163] In 2010/11, drought and heatwave caused over 16,000 hectares of the Northern Jarrah Forest to suddenly collapse and die, with mortality rates 10.5 times more than normal.[164] This included trees at least 100 years old that had successfully withstood fire, drought and heatwaves for a century or more.[165]

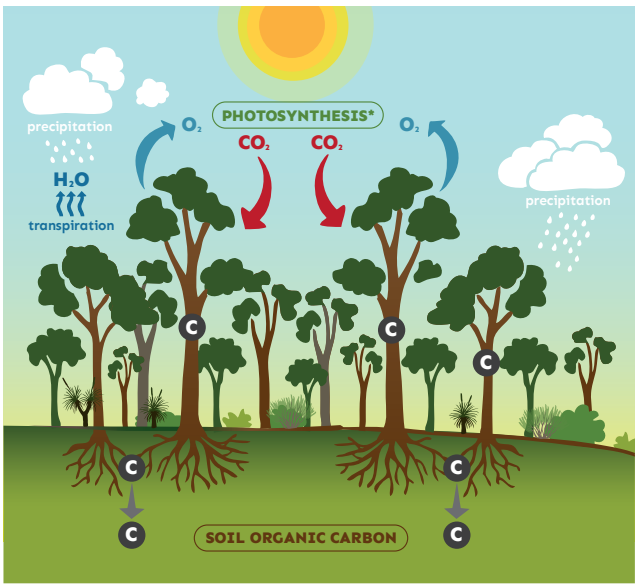
The most impacts of tree mortality were associated with rocky outcrops, areas of shallow soils and/or dense regrowth including some areas of dense mine site rehabilitation.[166]

That same drought and heatwave also killed vegetation from Rockingham to Eneabba, caused coral bleaching in Ningaloo, saw the loss of sea grass and kelp, was followed by crashes in Carnaby's cockatoo populations and decline in the breeding success of little penguins.[167] Murdoch University lecturer and Kings Park Science research scientist Dr Katinka Ruthrof called the impacts staggering and said our ecosystems are more vulnerable than we think.[168]

Declining rainfall and regolith drying, more unplanned, intense fires and declining productivity places stress on tree growth and compromises biodiversity in the Northern Jarrah Forest.[169] There is a risk (predicted with a high degree of confidence) that under hotter and drier conditions with more fires the Northern Jarrah Forest would transition to a new state or collapse.[170] If the regenerative capacities of the dominant canopy tree species are exceeded a long lasting or irreversible transition to a new ecosystem state is projected with loss of characteristic and framework species including loss of some narrow range endemics.[171]

The final draft of the Working Group II contribution to the *Sixth Assessment Report* of the Intergovernmental Panel on Climate Change says the resilience and adaptive capacity of the Northern Jarrah Forest is being reduced by ongoing land clearing and degrading land management practices.[172] It identifies two adaptation options that can substantially reduce the risk described in the above paragraph: increased capacity to extinguish wildfires during extreme fire weather conditions and avoiding and reducing forest degradation from inappropriate forest management practices and land use.[173]

Our forests, in addition to their intrinsic value, are our buffer against climate change. They can reduce carbon emissions, decrease temperature, and reduce the decline in our rainfall – but only if clearing stops.



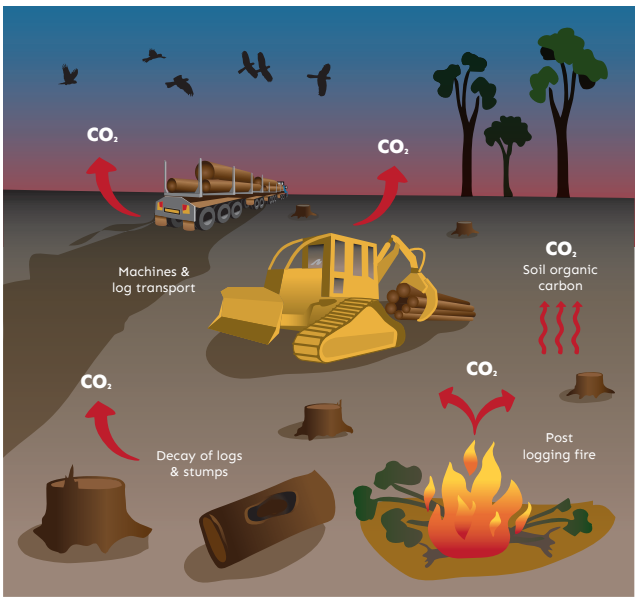
Forests and carbon emissions

When alive, trees absorb and store carbon. Once dead, they don't grow and therefore don't absorb carbon. When rotting or burning, they emit carbon. In 1980, around 28 million tonnes of carbon were released through vegetation clearing, and in 1990 land-use changes that were mainly vegetation clearance contributed to 22% of Australia's greenhouse gas emissions.[174]

Western Australia's living forests remove part of the excess carbon in our atmosphere that is causing our climate to change.

The 2010/11 collapse of trees in the Northern Jarrah Forest converted around 49.3 tonnes of carbon per hectare from live trees to dead trees that no longer absorbed carbon because they were no longer growing.[175] The rate of emissions from dead trees depends on their rate of decay – it is slower while the dead trees are standing and faster once they are lying in contact with the ground.[176]

By 26 months, regrowth in the drought affected forest had replaced over 80% of the original mass, counteracting most of the carbon loss from the decaying dead trees.[177] Whether that will be a temporary or permanent buffer remains to be seen. It depends on whether the young regrowth remains undisturbed until it has matured enough to withstand further disturbance, such as drought or fire.[178]



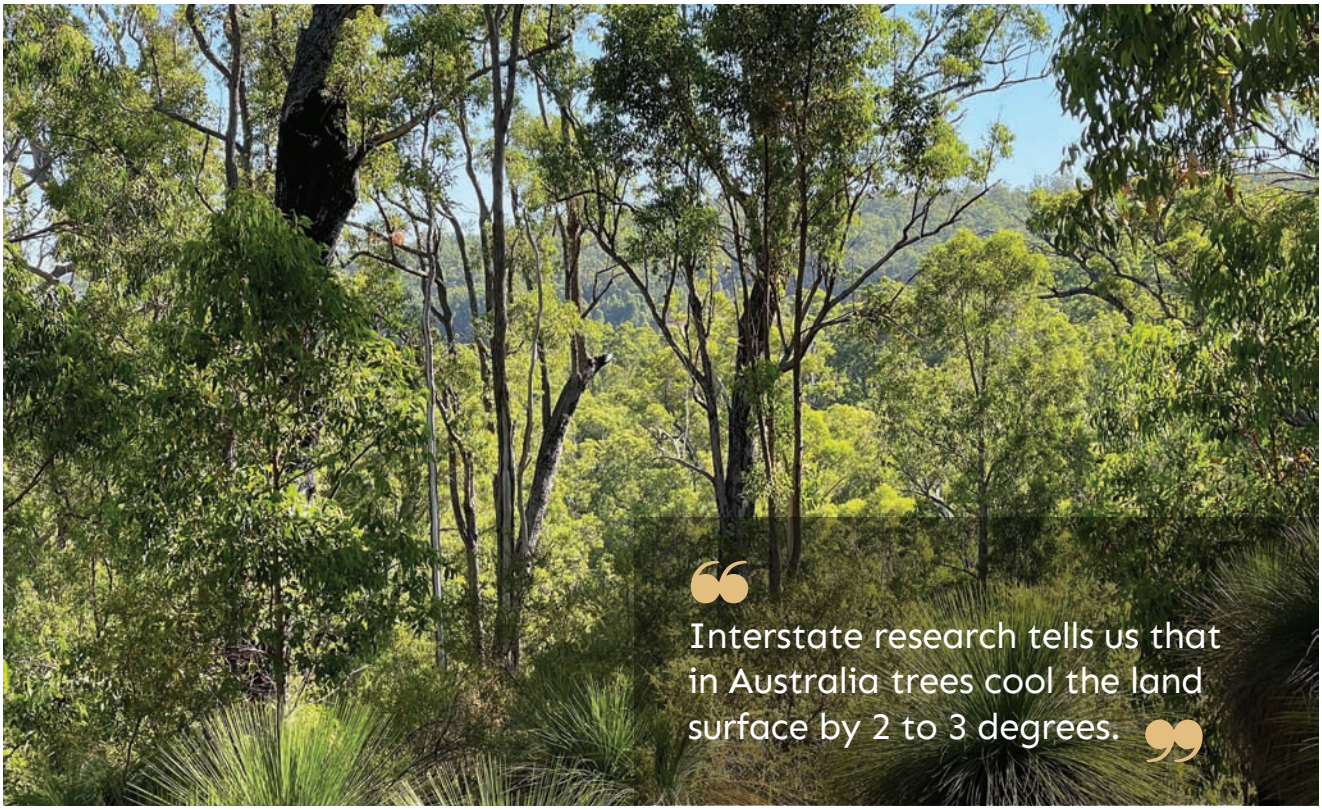
The chances of achieving this are best maximised by implementing, now, the climate change adaptation options identified by the Working Group II contribution to the *Sixth Assessment Report* of the Intergovernmental Panel on Climate Change, described above. Ongoing land clearing and degrading land management practices in the Northern Jarrah Forest, including clearing for bauxite mining, must stop. Otherwise, in a drying/heating climate, regrowth is unlikely to grow to the extent of the individuals that died[179] and vulnerable portions of forests could become carbon emissions sources rather than carbon emissions sinks.[180]

Forests and temperature

Our forests keep us cooler.

Over the last century Australia has warmed on average by around 1 degree Celsius, with an increase in the frequency of hot days and nights and a decrease in cold days and nights.[181] Forest clearing over large areas affects temperature variation.[182] Vegetation clearance adds to temperature increases.[183] Interstate research tells us that in Australia trees cool the land surface by 2 to 3 degrees.[184]

The 2010/11 tree collapse in the Northern Jarrah Forest occurred in patches. The microhabitat of the affected patches then changed dramatically, with solar radiation, ground level temperatures and wind speed all increasing.[185] When this happens, the remaining trees and understorey, and fauna, are likely to be impacted.[186] As indeed are people.



Dwellingup forest included in the proposed mining expansion area. *Photo: Jess Beckerling*

Clearing for bauxite mining, Serpentine Dam 2020. *Photo: Jeremy Perey*

Forests and rainfall

As stated above, rainfall in South West WA has declined by about 20% since the 1970s.[187] When rainfall reduces, water run-off reduces even more because the dry soil soaks up the water - the 20% decline in rainfall has reduced the amount of water running into our reservoirs by about 80%.[188]

Most of Perth's reservoirs are in the Jarrah Forest region.[189]

A 2013 research paper by Mark Andrich and Jorg Imberger indicated that half the reduction in rainfall in the escarpment area to 2000 is attributable to deforestation.[190] This is consistent with other research indicating that vegetation clearing adds to reductions in rainfall and that part of Western Australia's rapid decline in rainfall was attributable to forest clearing.[191]

Reduced rainfall impacts on humans directly. To maintain our water supplies, the Water Corporation has developed desalination plants[192] and expanded use of groundwater.[193] But both of these (especially desalination plants) increase the cost of our water and also hugely increase our carbon emissions.[194]

Reduced rainfall also has a negative impact on globally unique flora and fauna, which also need water to survive. Mainland Quokkas and Forest red-tailed black cockatoos have high water needs for example (discussed elsewhere in this paper). Reference material for Jarrah forest silviculture produced by the Department of Parks and Wildlife in 2015 says:

- Rainfall changes will increase moisture stress and may affect health and species composition in some places, especially areas of low rainfall and shallower soil
- The most immediate effect is likely to be on plants and animals at streams and in places with shallower soils
- Some perennial streams are now seasonal
- The period of flow has decreased in many seasonal streams
- Associated with these changes, some species have become less abundant[195]

> "Part of Western Australia's rapid decline in rainfall was attributable to forest clearing."

Rehabilitated mine sites vs intact forests

Bauxite mining clears thousands of hectares of the Northern Jarrah Forest and eventually replaces it with a new ecosystem that seeks to replicate elements of the forest that the miners removed. This takes many decades to centuries, and it does not restore the forest to what it was before mining.[196] Total restoration is not possible[197] – after all, the bauxite-containing part of the forest and all of the original vegetation has been permanently removed. The aim of rehabilitation is a self-perpetuating similarity or approximation to the original forest that was removed for mining.[198] This is being attempted in a drying climate, which increases the risk of failure substantially - climactic extremes disrupt and slow mine site rehabilitation.[199]

Reference material for Jarrah forest silviculture produced by the Department of Parks and Wildlife in 2015 says:

- Bauxite mining significantly affects biodiversity because it removes all vegetation and a substantial part of the soil profile from the site[200]
- Despite successes in restoring understorey species, structural complexity will not be restored for many decades or longer
- Rehabilitation will have a negative effect on a number of species in riparian zones because it reduces streamflow[201]

Willowdale bauxite mine, March 2022. *Photo: Jess Beckerling*

Similarly, the Department of Biodiversity, Conservation and Attraction's 2018 overview on forest management says that notwithstanding rehabilitation, there are enduring impacts on habitat and biodiversity, soils, water, carbon, production of wood and other forest produce, and recreation values.[202]

STANDARDS FOR REHABILITATION

The standard for Alcoa's rehabilitation is contained in publicly available 'completion criteria', which are regularly reviewed by the Mining and Management Program Liaison Group, an interagency group chaired by the Department of Jobs, Tourism, Science and Innovation.[203] This Department is responsible for state agreements, including the bauxite-mining agreements that Western Australia has with Alcoa and South32.

The current completion criteria were established following a review in 2014, and apply from 2016 onwards[204] until replaced following some future review. The completion criteria aim for a rehabilitated mine site that serves multiple purposes, not only biodiversity. For example at page 9 criterion 4.2.1 (Timber production) states "There is an adequate density of both Jarrah and Marri to meet timber production requirements. The timber production landuse [sic] criteria only apply to the percentage of rehabilitated area that had a timber production landuse prior to mining, i.e. if 15% of the area mined had no timber production potential, then only 85% of the rehabilitated area needs to meet the timber production landuse criteria." On page 10, Attachment 1 says "The stand stocking (usually expressed in terms of the number of stems per hectare) of restored overstorey needs to be high enough to satisfy timber production values, but not so high as to exclude understorey species, or compromise the health of overstorey through competition effects."

Now that the State Government has committed to ending native forest logging by 2024, this completion criterion will need to be abandoned.

Past standards for rehabilitation have not always sought similarity to the pre-mined forest. It is only since 1988 that endemic species (principally Jarrah, Marri and Blackbutt) have been used for rehabilitation.[205] Until then, exotic pine trees[206] and dieback resistant exotic eucalypts were used instead.[207] This was because many endemic species (including Jarrah) are susceptible to 'dieback' - a pathogen-caused root and collar rot that deprives the plant of water.[208] The use of endemic species for rehabilitation only started after it was discovered in the 1980s that Jarrah could survive in rehabilitated areas despite the soil containing the dieback pathogen.[209] As a result of past practice, as at the end of 2006, 31% of rehabilitated areas were non-endemic vegetation.[210]

Rehabilitated site at Huntly mine, a few km east of Del Park Road, 2018. Area was burnt a year or so prior. High stem density of trees, not much diversity in understory vegetation and not many fire resprouter species. *Photo: Jeremy Perey*

As the non-endemic rehabilitated sites are logged for timber, Alcoa has been changing them over to endemic species.[211] However changing an already-established rehabilitated site is difficult, expensive, and often unsuccessful.[212] The quality of those sites is therefore still sometimes lower than that of more recent sites.[213]

Knowledge about how to make rehabilitated mine sites more like intact forest is imperfect and evolving. The quality of rehabilitated mine sites varies, reflecting the knowledge levels of the time. Earlier sites had soil surface instability and retarded tree growth because of inadequate site preparation, species selection, revegetation techniques and nutrition – the exotic eucalypt trees were the most successful under those conditions.[214] The current completion criteria now require rehabilitated sites to have a minimum average of 60% of the plant species richness of intact forest by 15 months.[215]

Plant species richness does not of itself restore the forest ecosystem. Alcoa concedes that most of its rehabilitated sites are less than 30 years old and achieving full ecosystem restoration may take centuries[216], during which our rainfall will continue to decline. Rehabilitated mine sites differ in very important ways from intact forest.

> “Alcoa concedes that most of its rehabilitated sites are less than 30 years old and achieving full ecosystem restoration may take centuries.”

Newly discovered in 2019, the scented fairy orchid, *Caladenia lateritica* is restricted to just a few northern jarrah forest plateau areas. *Photo: Kingsley Dixon*

FAUNA DIFFERENCES BETWEEN REHABILITATED MINE SITES AND INTACT FOREST

One difference between rehabilitated mine sites and intact forest is that fauna displaced by bauxite mining do not necessarily return to rehabilitated areas and use them in the same way they did before mining.

In 1978, a technical advisory report provided to the Environmental Protection Authority said: "We disagree with Alcoa (WERMP, p. 474) that the impact on native species is reversible. The removal of the dominant plant species, and permanent changes to leaf-litter characteristics, soil texture, drainage, nutrient levels, and micro-environment may preclude re-establishment of much of the natural ground vegetation and hence of the native fauna."[217]

That prediction was borne out by the low quality of early rehabilitation. It did not support fauna recolonisation; it had low ground and understorey cover, low plant species richness, low biomass and no Jarrah.[218]

As indicated above, a higher level of plant species richness is now required. But faunal recolonisation takes more than returning the vegetation.

According to research co-authored and co-funded by Alcoa, the overall level of fauna species richness and diversity present at rehabilitated mine sites now approaches that of intact forest.[219] But it can take decades or centuries for some species to recolonise rehabilitated mine sites, some species may never return, some species may return but not stay and some species return but do not use the area in the same way as before.[220] Factors that can influence whether, when and for how long a particular species returns include the structural complexity of the area, the amount and energy value of the food it provides, the amount and quality of shelter it provides, whether predators are present, and how mobile the species is.[221]

For example:

- Some reptiles, for example some skinks, prefer intact forest to rehabilitated mine sites[222]
- Some animals that feed on those skinks do not seem to return to rehabilitated mine sites[223]
- Animals that need very specialised habitat and are highly vulnerable to habitat clearance and fragmentation may not return to rehabilitated mine sites[224]

Mardo. *Photo: Lyn Alcock*

Chuditch. *Photo: Clarissa Human*

- Although an animal may be observed at a rehabilitated mine site, its needs are not necessarily being met to the same extent as by intact forest.[225] Examples include Mardo, Chuditch and some skink species.[226] See also the part of this paper comparing threatened black cockatoo use of rehabilitated mine sites and intact forest
- Although it becomes more similar over time, there are distinct differences between the invertebrate species composition of rehabilitated mine sites and that of intact forest.[227] Invertebrates play a strong role in many ecosystem functions and processes[228]
- Not all taxa have been studied[229]

Skink. *Photo: Lyn Alcock*

Brush-tailed phascogale. *Photo: Shaun A Welsh*

From a fauna perspective, the two most significant weaknesses of rehabilitated mine sites are:[230]

- Rehabilitated mine sites lack, and will continue to lack for a century or more, the tree hollows that some fauna species need in order to survive. With rehabilitated areas not using endemic trees until 1988, rehabilitated mine sites will likely not provide those hollows until 2088 at the earliest. By then it may well be too late for some species. As discussed elsewhere in this paper, the Northern Jarrah Forest's three threatened species of black cockatoo need tree hollows of appropriate size in order to breed. Some mammals, for example Brushtail possums and Brush-tailed phascogales, also need tree hollows for breeding and shelter.[231]

  In 2018 Alcoa funded BirdLife WA over 3 years for a project that included installing 25 Cockatubes (a type of artificial nesting box) within its footprint at Dwellingup, Harvey, Kwinana and Mandurah.[232] Although these nest boxes were installed at some Alcoa rehabilitation sites in 1993/94 and most of them were used, it is considered impractical to install nest boxes in all rehabilitated areas[233]

Photo: Donna Chapman

- Rehabilitated mine sites also lack the old rotting wood and low coarse woody debris that is needed by some fauna and also some species of fungus. This too will take a very long time, possibly centuries, to change.[234]

RESPROUTING DIFFERENCES BETWEEN REHABILITATED MINE SITES AND INTACT FOREST

The Northern Jarrah Forest includes resprouting species of vegetation, that is, they can regrow after disturbances such as fire, drought and grazing.

Resprouters are therefore extremely important for the resilience of the forest, as was demonstrated by the regrowth that occurred after the calamitous tree mortality of 2010/11 from drought and heatwave.

The current completion criteria require rehabilitation sites to have at least 200 surviving resprouter species per hectare.[235]

Notwithstanding this, rehabilitated mine sites historically have fewer resprouters than intact forest.[236] Although common in intact forest, resprouters are difficult to re-establish in rehabilitated areas and are therefore historically absent or under-represented there.[237] This has serious ramifications for the resilience and carbon storage capacity of the Northern Jarrah Forest.

As the frequency and intensity of disturbances like drought and fire in the Northern Jarrah Forest increase with climate change, those ramifications are magnified because:

- Resprouting capacity is limited and can become depleted with repeated disturbance[238]
- Resprouted vegetation is vulnerable until it has developed bark thick enough to withstand disturbances like fire and enough carbon stores to withstand disturbances like drought[239]

Boddington bauxite mine, March 2022. *Photo: Jess Beckerling*

SOIL DIFFERENCES BETWEEN REHABILITATED MINE SITES AND INTACT FOREST

The Northern Jarrah Forest grows and relies on very deep regolithic soils containing both soil moisture and groundwater, but the moisture in the regolith has decreased.[240]

The best Jarrah grows on the best bauxite deposits.[241] Bauxite mining removes metres of very porous bauxite material and significantly reduces the soil moisture storage capacity of the landscape.[242]

The tree deaths that occurred following the drought and heatwave of 2010/11 generally[243] occurred in very dry patches,[244] in a manner consistent with earlier research associating drought impacts with shallow soils of limited water storage potential.[245]

Jarrah tends to maintain relatively high transpiration in summer because ordinarily its deep roots can access water, but there are substantial negative impacts for the tree if it can't access water because of soil that is shallow or has low water holding capacity.[246]

Shallower soil was also a key driver of mortality for mid-storey *Banksia grandis* trees in 2010/11.[247]

All these water effects will become more pronounced in a drying climate.

There are further differences between the soil of rehabilitated mine sites and that of intact forest. Soil properties affect plant growth. A 2017 paper[248] indicates that there are significant soil differences, and although these reduce over time there are still several differences after 22 years, indicating soil development is yet to be completed.[249]

That study cited earlier research indicating that the soil of rehabilitated mine sites takes 8 years to reach a similar microorganism level to intact forest, while nematodes recover in the short to medium term[250] and nitrogen, phosphorus and potassium levels (from fertiliser) leach and decrease over time.[251]

There is debate about how long it takes for soil carbon levels to return to that of intact forest after clearing. It has been suggested that this is attributable to studies having different timeframes.[252] Studies also differ in context, for example mine site rehabilitation, reforestation of pasture, and logging forests repeatedly for timber.

The 2017 paper referred to above cites earlier research indicating that it takes 18 years for soil carbon levels to return at rehabilitated mine sites.[253] However a 2008 paper suggests that the form of that carbon may be short-lived particulate organic matter that readily decomposes and does not contribute significantly to carbon sequestration; the capacity of rehabilitated mine sites to accumulate carbon in soil and sequester it long term may be more limited than superficial carbon measurements suggest.[254]

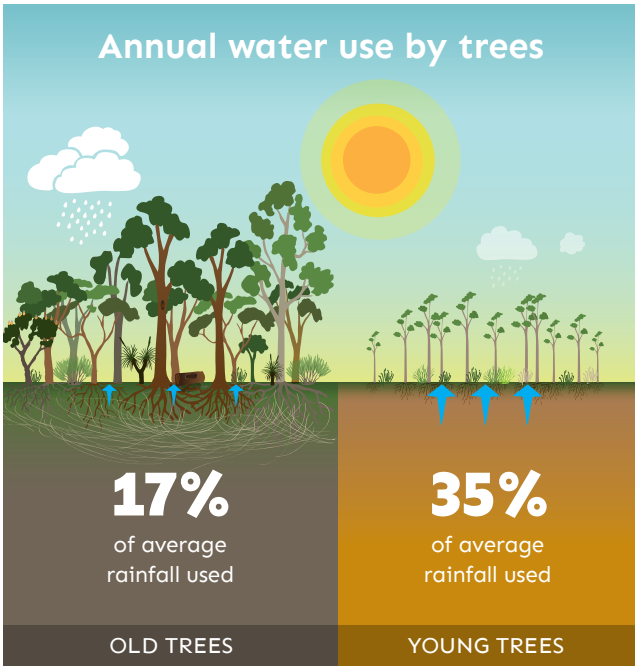
Studies from other contexts indicate that it takes decades or even centuries for soil carbon levels to return when land is revegetated after clearing:

- A WA government website says it takes at least 30 years when carbon farming on former pastureland[255]
- A 2016 analysis of global literature concluded it takes at least 60 years in many production forests[256]
- A 2017 paper says long term modelling and studies show soil carbon is decreased for 300 years or more when primary forests are logged and harvested repeatedly[257]

HIGHER WATER USE BY REHABILITATED MINE SITES THAN INTACT FOREST

As stated above, rainfall in South West WA has declined by about 20% since the 1970s.[258]

A 2009 CSIRO paper reported on a study at Jarrahdale, Serpentine and Dwellingup in the Northern Jarrah Forest that investigated whether stands of larger, older, old growth Jarrah trees use less water than stands of smaller, younger, regrowth Jarrah trees.[259] The answer was emphatically yes. Annual water use by the older trees was half that of the younger trees, the older trees using approximately 17% of average annual rainfall and the younger trees using 35% of average annual rainfall.[260]



A comparison was then made with data from rehabilitated bauxite mine sites. A 1993 study indicated a rehabilitated mine site at Del Park used 50% of annual rainfall.[261] A 2003 study estimated that a very dense stand of Jarrah at a rehabilitated mine site at Huntly used 50-60% of annual rainfall, while a sparse stand of Jarrah at a rehabilitated mine site at Worsley (South32) used 15% of annual rainfall.[262]

The CSIRO report's findings are consistent with evidence that streamflow (rainfall runoff)[263] decreases at rehabilitated mine sites because of vigorous early plant growth.[264] It is not yet known whether the decrease is temporary or permanent.[265]

In 2018, the Institute of Foresters of Australia calculated (using research data from Alcoa) that the amount of water being lost to rehabilitated mine sites instead of going to adjacent intact forest and streams was 500,000 litres per hectare or 60 billion litres overall – more than the annual production of water by the Kwinana desalination plant.[266]

Notwithstanding higher water use, the areas of the Northern Jarrah Forest most impacted by tree mortality during the 2010/11 drought and heatwave included some areas of dense mine site rehabilitation,[267] as noted above.

At the same time as rehabilitated mine sites in the Northern Jarrah Forest are taking a disproportionate share of declining annual rainfall, groundwater levels are falling to the extent that disappearance of regolith groundwater has been predicted in some areas.[268]

Although it has been suggested that Jarrah trees rely less on groundwater below 5 metres than on soil moisture above the water table[269] and that Jarrah forest is conservative in water use where access to deep groundwater is limited,[270] the tree mortality of 2010/11 shows that the resilience of the Northern Jarrah Forest is not infinite.

A 2019 article observes[271] that several aspects of the change of water balance have not been resolved, in particular what will happen when regolith is seasonally dried to bedrock, and if the forest canopies are currently being maintained by deep soil water stores then changes are likely when the forest is forced to rely solely on annual rainfall. The paper suggests[272] that without the buffer of stored soil moisture the forest canopy will change to reflect drier rainfall conditions, which may entail a recession of canopies across the forest and episodic deaths in response to extreme temperature events. The paper says that while tree mortality has previously occurred in areas where soil water storage is small, on drying of the regolith this may extend across the whole landscape.[273]

This is the context in which rehabilitated mine sites of thirsty young vegetation are being created in the Northern Jarrah Forest.

TREE ARCHITECTURE DIFFERENCES BETWEEN REHABILITATED MINE SITES AND INTACT FOREST

Jarrah trees show some plasticity depending on the resources available to them. The stems, crowns, branches and leaves (above-ground tree architecture) of Jarrah trees from rehabilitated mine sites differ from those of Jarrah trees from intact forest; this is because of their different growing conditions from intact forest, including highly modified substrate (as described above) and more abundant water, nutrients and light.[274]

Photo: Jess Beckerling

There are also significant differences in root growth and access to soil resources.[275] These are regulated by the substrate.[276] Jarrah trees from intact forests have two tiers of roots – shallow lateral roots and deep sinker roots for accessing water.[277] Young Jarrah trees from poorer rehabilitated sites have a lot of roots and they penetrate only to 0.5 metres.[278] Jarrah trees from better rehabilitated sites have fewer roots but they penetrate deeper.[279]

If (as seems likely) the more abundant water, nutrients and light available at rehabilitated mine sites reduces over time, the architecture of those Jarrah trees may need to change again in the long term if they are to survive.[280]

NB: That study did not consider the impacts of changed tree architecture on faunal food and shelter resources. For example, what if any difference is there to the amount and quality of flowers and fruit produced? And what if any difference is there to bird foraging and roosting activity in the narrower crowns and denser canopy?

BIGGER, OLDER TREES STORE MORE CARBON

In her 2021 book 'The Arbornaut' tree expert Meg Lowman PhD repeatedly stresses that bigger, older trees absorb and store more carbon from the atmosphere than smaller trees do.[281]

Modelling done in 2006 indicates that it takes 152 years for a clear-felled forest to reach 90 per cent of the carbon carrying capacity of an old forest.[282]

Modelling done in 2015 indicates that over 100 years, net carbon stocks are higher when native forest is conserved rather than logged or cleared, even when wood products from timber production are taken into account.[283]

Bauxite mining removes the forest's carbon storage capacity when it is cleared. Jarrah trees on rehabilitated sites grow faster than in intact forest, but nonetheless take 2-3 years to reach 5 metre (sapling) size and 8-10 more years to reach 10 metre (pole) size.[284] In total, that is a lot of years of missed carbon storage opportunity.

Proposed expansion area in Dwellingup forest.
Photo: Jess Beckerling

PUTTING THE PICTURE TOGETHER

What do these differences between rehabilitated mine sites and intact forest mean for the climate resilience of the region? How do rehabilitated mine sites compare with intact forests in terms of reducing carbon emissions, reducing temperature and shielding us from rainfall decline? We think rehabilitated mine sites score substantially lower:

Event	Effect on carbon, temperature, water
Site is cleared for bauxite mining	• Carbon absorption stops • Carbon emissions from burning stumps and vegetation after trees are cleared • Loss of soil carbon • Ground level temperature in that area rises
Bauxite is removed	• Soil becomes shallower and less moisture-retentive. Such soils are associated with plant vulnerability to drought
Rehabilitation begins	• Revegetation uses more water than original forest, reducing water for streams and reservoirs and surrounding forest and increasing drought susceptibility. It is unknown whether this is temporary or permanent • Carbon absorption resumes • Ground level temperature reduces as revegetation grows
Rainfall declines as predicted	• Scenario A: Plasticity of Jarrah trees allows them to change their architecture and survive with less water • Scenario B: Jarrah trees cannot change their architecture to survive with less water and tree mortality occurs, creating dead patches similar to 2010/11. As in 2010/11, in those patches ground level temperature rises, carbon is no longer absorbed by the dead trees, and carbon is emitted as the dead trees decay or burn
Disturbance (e.g. drought, fire) causes tree mortality at some point in both intact forest and rehabilitated mine sites	• In the dead patches of both, as in 2010/11 ground level temperature rises, carbon is no longer absorbed by the dead trees, and carbon is emitted as the dead trees decay or burn • In the intact forest, as in 2010/11, there is about 80% regrowth after 26 months, reducing temperature and counteracting carbon emissions from dead trees • In the rehabilitated mine sites, there are fewer resprouters so recovery is constrained

ASSESSING THE CUMULATIVE IMPACTS OF PRESSURES ON THE NORTHERN JARRAH FOREST REGION

KEY POINTS:

Given the extent of the pressure on the Northern Jarrah Forest, including from bauxite mining, a strategic assessment of the cumulative effects on the region by the Environmental Protection Agency (EPA) is merited, to inform future management decisions.

There are various mechanisms in the Environmental Protection Act 1986 that allow the EPA to do this.

One mechanism is that the Minister for Environment can request a strategic assessment under section 16(e) of the Act. Via this mechanism, in 2021 the EPA provided strategic advice to the Minister on the potential cumulative impacts of proposed activities and developments on the environmental, social and cultural values of Exmouth Gulf.[285] The EPA recommended: a very high level of protection for parts of the Exmouth Gulf, that any future activities and development be compatible with protection of key values, and an integrated management approach to conserve and enhance those key values.[286] The outcome was that the WA government announced it would establish a new marine park to provide a high level of protection for parts of the Exmouth Gulf and Class A reserves for the protection of local areas of significance.[287]

Another mechanism is via the ordinary course of the EPA conducting an environmental impact assessment under Part IV of the Act. The proposals by Alcoa and South32 to clear more forest are currently going through the Part IV process. The EPA is required to consider the effect of the proposals on the environment. In 2020, the Environmental Protection Act 1986 was amended to say that a reference in the Act to the effect of a proposal on the environment includes a reference to the cumulative effect of impacts of the proposal on the environment [our emphasis].[288] That amendment clarified the existing law rather than changing it:

- (From Minister Stephen Dawson's Second Reading speech in the Legislative Council) "Part IV of the Environmental Protection Act provides for the Environmental Protection Authority to assess the environmental impacts of proposals and planning schemes, which are likely, if implemented, to have a significant effect on the environment... In response to calls from stakeholders for express consideration of cumulative impacts, the EP amendment bill clarifies that the effect of a proposal includes its cumulative impacts. This puts it beyond doubt that the EPA is able to take a regional or strategic approach in undertaking its assessment and making recommendations. Provisions dealing with strategic assessments have been clarified using terminology consistent with that used in other jurisdictions. These amendments will align the EPA's ability to conduct strategic assessments with similar processes used in other jurisdictions." [289]
- (From the Explanatory Memorandum) "It also introduces a new section 3(1B) into the EP Act which states that the effect of a proposal on the environmental includes its cumulative impacts. While this has been the understanding of the current provisions, this is now clarified. The term "cumulative impacts" relies on its ordinary meaning, which may change over time in a similar manner to the term "significant" used in the EP Act" [290]

A third mechanism is section 16(j) whereby the EPA has power to publish reports on environmental matters generally. In 2019, pursuant to this power, the EPA published advice regarding Carnaby's cockatoo in environmental impact assessment in the Perth and Peel Region.[291]

LACK OF TRANSPARENCY OF STATE AGREEMENTS ABOUT BAUXITE MINING

KEY POINTS:

Bauxite mining is carried out pursuant to state agreements between the Western Australian government and the bauxite mining companies, that are ratified by Parliament.

State agreements are not available to the public, or even to parliamentarians, in an up to date consolidated form unless a request is made to the Department of Jobs, Tourism, Science and Innovation.

Following repeated questions in Parliament, the McGowan Government committed in June 2021 to making state agreements publicly available. It has not yet done so.

Until this commitment is fulfilled, public and parliamentary scrutiny of State Agreements will continue to be constrained.

There is a lack of transparency about state agreements, including the bauxite-mining agreements the WA government has with Alcoa and South32.

Following repeated questions in Parliament during the 40th Parliament (2017-2021) the McGowan government committed in June 2021 to making up to date consolidated copies of state agreements between the WA government and companies publicly available.[292] It has not yet done so. All that gets published is a list of what state agreements exist.[293]

If a State agreement has been ratified by parliament then the Act gets published on the Western Australian legislation website, but the state agreement does not appear in an updated consolidated form there.[294]

To get a current consolidated copy of a state agreement, people have to ask the Department of Jobs, Tourism, Science and Innovation, which holds state agreements on behalf of the government. Alternatively, members of parliament can request a copy of a state agreement anonymously via the parliamentary library.[295]

In 2017, a question in parliament resulted in consolidated versions of the following state agreements being tabled by the government and thereby made publicly accessible:

- Alumina Refinery Agreement (the principal agreement)
- Alumina Refinery (Wagerup) Agreement
- Alumina Refinery (Pinjarra) Agreement
- Alumina Refinery (Worsley) Agreement[296]

However, the cover page to the state agreements stated that they were not an official version and that accuracy could not be guaranteed, and a disclaimer stated that no warranty was given that they were free from error or omission, that they included all amendments or as to the accuracy of any information in them.[297]

The failure to publish accurate consolidated versions of state agreements means that when the WA parliament debates bills amending state agreements (as it regularly does) even the members of parliament cannot see exactly what is being amended.[298] The quality of parliamentary scrutiny of such bills is therefore compromised.

It was concerns about lack of transparency of state agreements that led to the repeated questions in parliament during the 40th parliament and thus the McGowan government's commitment (not yet fulfilled) to making them publicly available.

Parliamentarians have also proposed that bills amending state agreements be referred to a parliamentary committee to investigate and advise parliament before the bill is debated about what the effect of the amendments will be if the bill is passed.[299]

CONCLUSION

The Jarrah Forest is a major component of a Global Biodiversity Hotspot that is under enormous cumulative pressure from a variety of sources.

A key risk of climate change is that the Northern Jarrah Forest will collapse or transition to a new ecosystem without its characteristic and framework species; however, the risk can be substantially reduced by avoiding and reducing clearing and forest degradation from inappropriate forest management practices and land use.

Bauxite mining is the primary cause of deforestation in WA's South West forests.

Bauxite mining has cleared at least 32,130 hectares (80 times the size of Kings Park) and fragmented 92,000 to 120,000 hectares of the Northern Jarrah Forest. The rate is accelerating – 11,290 hectares (over a third) of that were cleared between 2010 and 2020. Bauxite miners Alcoa and South32 now propose to clear a further 11,109 hectares and fragment another 70,211 hectares. It has been estimated that eventually up to 83,000 hectares will be cleared and 337,000 hectares fragmented for bauxite mining. Most of the forest between Collie and Armadale is expected to be fragmented by bauxite mining by 2060.

Western Australia does not keep central or complete records of how much deforestation is happening and the contribution each sector makes to that.

The Northern Jarrah Forest, including the areas proposed to be cleared and fragmented by bauxite miners Alcoa and South32, is habitat for threatened species including mainland Quokkas, Carnaby's cockatoo, Baudin's cockatoo and Forest red-tailed black cockatoo. For every one of them, habitat alteration/loss and fragmentation is a major contributor to their decline. Indeed, their Recovery Plans all refer specifically to the contribution made by mining. There is no evidence that more habitat can be lost without significant adverse impacts.

Their habitat needs to be conserved. Their Recovery Plans have not been effective in achieving this, not least because no funding is specifically allocated for implementation of recovery actions.

Bauxite mining companies rehabilitate their mine sites when mining is finished, but there are many important differences between intact forest and rehabilitated mine sites. Forests remove carbon from the atmosphere, decrease temperature, reduce rainfall decline, and provide fauna habitat – and intact forest significantly outperforms rehabilitated mine sites on all of these fronts.

For all of these reasons, further deforestation by bauxite mining companies must not be authorised. Further, there needs to be an inquiry into the efficacy of Recovery Plans and how to take more effective action to arrest the decline of threatened native forest species.

In addition, given the extent of the pressure on the Northern Jarrah Forest from a wide variety of sources including bauxite mining, the Environmental Protection Agency needs to carry out a strategic assessment of the cumulative effects on the region to inform future management decisions. There are various mechanisms in the Environmental Protection Act 1986 that allow the Environmental Protection Agency to do this.

Bauxite mining is carried out pursuant to State Agreements between the Western Australian government and the bauxite mining companies, that are ratified by Parliament. It is not acceptable that public and Parliamentary scrutiny of State Agreements is constrained because up to date consolidated versions of State Agreements can only be accessed via request to the Department of Jobs, Tourism, Science and Innovation. The McGowan government must fulfil the commitment it made in June 2021 to making up to date consolidated versions of State Agreements publicly available.

RECOMMENDATIONS

WA Forest Alliance, the Wilderness Society and the Conservation Council of Western Australia together make five recommendations:

1	That no further clearing or fragmentation of native forest in the Northern Jarrah Forest for mining be authorised.
2	That the Environmental Protection Agency undertake a strategic assessment of the potential cumulative impacts of past, current and proposed activities and developments (including but not limited to bauxite mining, logging and prescribed burning) on the Northern Jarrah Forest.
3	That there be a WA government inquiry into: **a.** The efficacy of current processes (including Recovery Plans and Habitat Protection Plans) in arresting the decline of threatened native forest species including mainland Quokkas, Carnaby's cockatoo, Baudin's cockatoo and Forest red-tailed black cockatoo. **b.** The obstacles to implementing recovery actions recommended by those processes. **c.** Whether there is a need for an emergency plan to arrest the decline of threatened native forest species including mainland Quokkas, Carnaby's cockatoos, Baudin's cockatoos and Forest red-tailed black cockatoos.
4	That the WA government create and maintain an up to date, publicly accessible central record of native vegetation and biodiversity data that shows and tracks its extent and condition across the State, including showing and tracking the proportion cleared in each bioregion by each sector.
5	That the WA government immediately make up to date consolidated versions of all State Agreements publicly available.

WA FOREST ALLIANCE

Wilderness Society
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27 The WA government keeps no record of clearing under Schedule 6 of the Environmental Protection Act 1986 or the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 because no application is made for clearing under those provisions. In the event of monitoring by the Department of Water and Environmental Regulation the onus is on the person who did the clearing to show that the clearing falls within the exemption provisions

28 The WA government keeps an internal record of prosecutions for offences under the Environmental Protection Act 1986, including but not limited to illegal clearing. Although it is understood that a summary of prosecutions has been publicly available in the past, this was not able to be located when a search was done on 5/03/2022

29 WA government clearing statistics for IBRA region https://www.dwer.wa.gov.au/clearingstatistics accessed 10/02/2022 and manually aggregated (breakdown is at Appendix 1)

30 Question On Notice No. 531 Op. Cit.

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35 Nick Kilvert (2020) Land clearing in Australia: how does your state (or territory) compare? Op. Cit. NB: WA's deforestation figures do not appear to be broken down in the National Greenhouse Gas Accounts to identify the particular forest or IBRA bioregion: Australian Government (2019) *National Inventory Report Volume 2* https://www.industry.gov.au/sites/default/files/April%202021/document/national-inventory-report-2019-volume-2.pdf page 323 and State and Territory greenhouse gas inventory data tables accessible via https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-2019/state-and-territory-greenhouse-gas-inventories-data-tables-and-methodology (go to WA tab) both accessed 28/02/2022

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41 Alcoa (2020) Annual Report Op. Cit. Part I page 6

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43 ibid pages 5-6

44 "Probable reserves" are the portion of a bauxite reserve where the physical and chemical characteristics and limits are known with sufficient confidence for mining economically and to which various mining modifying factors have been applied.

45 "Proven reserves" are the portion of a bauxite reserve where the physical and chemical characteristics and limits are known with high confidence for mining economically and to which various mining modifying factors have been applied.

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