Attachment 4
to
Item 4.3.1

Koala habitat restoration guidelines

Date of meeting: 20 June 2023
Location: Council Chambers
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NSW GOVERNMENT

Department of Planning and Environment

Koala habitat restoration guidelines

A practical guide to identify, connect and restore koala habitat in New South Wales

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Cover photo: Regenerating koala habitat along Byron Creek in Binna Burra, New South Wales. This community event was hosted by Bangalow Koalas and involved 180 volunteers who planted 2600 koala and rainforest trees. Property Shot Photography

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The term ‘Aboriginal’ is used in this document except where referring to both Aboriginal and Torres Strait Islander peoples. ‘First Nations’ recognises Aboriginal and Torres Strait Islander people as the sovereign people of this land. It recognises various language groups as separate and unique sovereign nations.

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1. Introduction

The koala (*Phascolarctos cinereus*) has suffered a dramatic decline in numbers and distribution since the arrival of Europeans in Australia. Most koala populations in New South Wales (NSW) now survive in increasingly degraded and isolated patches of habitat, which are subject to intense and ongoing pressures (Office of Environment and Heritage (OEH) 2018a).

In NSW, the koala is listed as vulnerable under the *Biodiversity Conservation Act 2016*. Koala populations in Hawks Nest/Tea Gardens, Pittwater, and between the Tweed River and Brunswick River east of the Pacific Highway face a higher risk of extinction and are listed as endangered. In February 2022, the koala was also listed as endangered in Queensland, NSW and the Australian Capital Territory under the *Australian Government's Environment Protection and Biodiversity Conservation Act 1999*.

The NSW Koala Strategy 2018 (OEH 2018b) highlights the need to support local communities to deliver on-ground actions that reduce threats to and protect koala populations.

Threats to koalas include:

- loss, modification and fragmentation of habitat
- diseases such as retrovirus (immune deficiency syndrome) and chlamydia (can cause blindness, infertility, severe infection and death)
- vehicle strike
- predation by dogs
- heat stress due to drought and heatwaves
- intense bushfires that scorch or burn the tree canopy
- increased competition for food and territory
- human-induced climate change (OEH 2019).

These habitat restoration guidelines acknowledge that minimisation of threats to koalas depends upon increased awareness and appreciation of wildlife by all Australians, leading to changes in the ways we live within our environment. To contribute to this, the guidelines provide evidence-based recommendations to help land managers, community groups and private landholders identify, connect and restore koala habitat using best-practice methods.

2. Koala management areas

Figure 1 Koala management areas (KMAs) in New South Wales. Source: DPE

The Department of Planning and Environment has designated 7 koala management areas (KMAs) in New South Wales (NSW; Figure 1). Seven KMAs were developed to broadly reflect the regional distribution of koalas and preferred koala food trees across NSW. They provide a basis for collecting information about koala tree use and facilitate koala conservation work such as monitoring, recovery, planning and assessment.

The KMAs are based on:

- landscape characteristics, particularly the geographic distribution of tree species koalas prefer to eat
- local government area boundaries for ease of natural resource management (Department of Environment and Climate Change 2008).

Habitat characteristics and threats are relatively consistent within each KMA, although local variations occur.

3. Koala habitat

Koalas can live sustainably in areas where:

- annual rainfall is above 500 millimetres per year
- maximum daily temperatures do not exceed 40°C for more than a few days, longer than this causes heat stress and mortality
- altitude is less than 1200 metres above sea level (Australian Koala Foundation 2019).

Koalas live in eucalypt-dominated woodland and forests. These include:

- coastal forests
- woodlands of the tablelands
- woodlands of the western slopes
- riparian vegetation of the western plains.

Koalas also use isolated paddock trees; trees planted as windbreaks, along fence lines and in utility corridors; as well as some non-native vegetation for shade and shelter.

3.1 Habitat requirements

3.1.1 Koala food trees

Koalas feed primarily, but not exclusively, on eucalypt leaves. They are known to use 137 tree species, of which 103 are of the genus *Eucalyptus* (Office of Environment and Heritage (OEH) 2018b). However, their diet is quite specialised. At a single site, an individual koala will get most of its nutrition from one or a few species (Figure 2).

Figure 2 Remnant koala habitat dominated by forest red gum (*Eucalyptus tereticornis*) and tallowwood (*E. microcorys*) with open grassy understory showing tree recruitment, Lismore Memorial Gardens. Photo: Tein McDonald

Food preferences can vary between regions and seasons. The palatability of individual trees within a single species may be influenced by soil properties (e.g. nutrients, salinity, clay/loam/sand), water availability (affecting leaf moisture), tree stress (disease, temperature) and/or tree genetics (OEH 2018a). There is still much to learn about what influences the nutritional quality of leaves koalas eat. Nutritional quality can vary within and between tree species, as well as from one area to the next.

The KMA revegetation fact sheets list tree species koalas are known to use in each koala management area (KMA):

- North Coast Koala Management Area (KMA 1) fact sheet
- Central Coast Koala Management Area (KMA 2) fact sheet
- South Coast Koala Management Area (KMA 3) fact sheet
- Northern Tablelands Koala Management Area (KMA 4) fact sheet
- Central and Southern Tablelands Koala Management Area (KMA 5) fact sheet
- Western Slopes and Plains Koala Management Area (KMA 6) fact sheet
- Far West and South-west Koala Management Area (KMA 7) fact sheet.

3.1.2 Other habitat requirements

Koala habitat is not just about food trees, it is also about access to shelter trees that allow koalas to meet their need for seasonal differences in tree use.

Koalas prefer areas that have:

- at least 30% of total canopy trees that are primary or secondary preferred food trees (McAlpine et al. 2007) – this percentage will vary with habitat size
- non-eucalypt trees and shrubs for shelter and other behavioural purposes; plants with dense foliage help koalas stay cool in summer, particularly with a drying climate (Lunney et al. 2012a, Crowther et al. 2014, Mitchell 2015)
- young and old food trees, with most trees having a diameter at breast height between 26 and 80 centimetres (Department of Environment and Climate Change 2008); koalas prefer resting in larger trees, but will eat foliage from young trees
- small trees can also be important for releasing small, rescued koalas (pers. comm.)
- water nearby (Smith et al. 2013) to provide trees with higher leaf moisture and water to drink
- a minimum habitat patch size of 2 hectares, although larger than 50–100 hectares is preferable to support a sustainable population (McAlpine et al. 2007); these values can vary greatly depending on the quality of the habitat and the region. In some areas (such as Canyonleigh in the Southern Highlands), minimum patch sizes are 100 hectares
- good connectivity to other habitat patches, however this is not always necessary as koalas can cover distances of several kilometres across open ground
- quality habitat adjacent to preferred food tree patches that includes rainforest, non-eucalypt swamp forests, wetlands, heathlands, grasslands, open paddocks and cropland without scattered eucalypts as these can provide for movement and connectivity across the landscape, places of refuge in time of heatwave and fire, and in some cases non-eucalypt food (Lunney et al. 2012a, Crowther et al. 2014, OEH 2018a).

3.2 How to identify active and potential habitat

It is important to understand the habitat preferences and distribution of a local koala population.

In 2019 the NSW Government released the Koala Habitat Information Base to support decision-making about koala conservation (Department of Planning, Industry and Environment 2019a and b). The database captures information about the distribution of koala populations, where preferred koala food trees are located, and koala sightings in NSW. This includes spatial layers such as the Koala Habitat Suitability Model (e.g. Figure 3), which measures the probability of finding koala habitat at a location, and the Koala Likelihood Map, which predicts the likelihood of finding a koala at a location.

Active and potential koala habitat can be identified by:

- the presence of preferred koala food trees, as listed in the KMA fact sheets (see section 3.1)
- historical or recent koala records, for example data collections in the BioNet Atlas (NSW BioNet 2021)
- the presence of koalas in trees
- the presence of koala faecal pellets (scats) under trees
- the presence of koala scratches on trees; scratches made by possums and goannas are similar to those made by koalas and scratches alone should not be considered a definitive indication of koalas.

More information on monitoring techniques for koala presence and activity is provided in section 6.

4. Considerations when restoring koala habitat

4.1 Stakeholder engagement

The first consideration before a koala habitat restoration project begins is to consult with people who have a direct or indirect stake in the site. It is particularly important to engage local Aboriginal people, local landholders and community groups.

Local Aboriginal people are deeply embedded in the geographic, occupation and land-management history of a particular place; engaging them early and ensuring they are kept abreast of the progress can ensure the project:

- avoids damage to cultural sites
- is informed by traditional ecological and cultural knowledge
- enhances opportunities for Aboriginal cultural heritage consultants and ranger teams to be engaged in the planning and implementation phases of the work (see Box 1).

Similarly, early engagement with landholders and people who have a neighbourhood or community interest in the management of the site can help to avoid or resolve potential conflicts where needs or values may differ.

This early engagement applies to both public and private land, and can improve community support for a project, streamline problem solving and optimise opportunities to link the particular koala restoration project to other potential habitats and corridors in the surrounding landscape.

Box 1: Engaging Aboriginal rangers

Aboriginal rangers are on the frontline of nature protection Australia-wide, delivering transformational benefits for people and nature.

Initiatives to enable First Nations people to gain meaningful employment in nature conservation are increasing in NSW, whether through statutory obligations placed on agencies arising from land claim decisions or through a community desire to build Indigenous capacity and support Indigenous-run enterprises.

Employment of Aboriginal rangers in nature conservation offers two-way benefits. Meaningful working partnerships with Aboriginal rangers provide social, cultural and economic benefits, including improving health, fuelling jobs, boosting economy, reinforcing culture, empowering women and strengthening community. A report commissioned by the Australian Government Department of the Prime Minister and Cabinet found that Indigenous land and sea management delivers up to three dollars' worth of environmental, social and economic value for every one dollar spent (Department of the Prime Minister and Cabinet 2016).

If you choose to engage an Aboriginal ranger group it is recommended to do so early in the process. Consultations can be undertaken during site assessments, early planning, undertaking of management actions and monitoring and evaluation.

To find out which would be the relevant Aboriginal ranger group in your area you can contact a number of different places, including the local Aboriginal Land Council, a local Indigenous Protected Area Manager, your biodiversity alliance, local Council and/or regional NSW Government Aboriginal Cultural Heritage Services to request an appropriate referral.

4.2 Aim and goals of habitat restoration

The aim of koala habitat restoration is to help conserve koala populations by reducing threats and increasing the quality, area and connectivity of existing and potential koala habitats. The quality of restoration aimed for is an ecologically functional local native ecosystem that supports healthy populations of koalas. The restored habitat is also likely to support a range of other native species.

4.2.1 Reference ecosystems

Irrespective of approach (see Section 5), the goal for any koala habitat restoration project should be to produce an ecological community modelled on a locally occurring remnant vegetation community, referred to as the 'reference ecosystem'. The use of a reference ecosystem is important for sites that are existing habitat as well as sites where habitat is being reconstructed through planting or direct seeding.

Reference ecosystems will be a specific ecological community, usually dominated by eucalypts, that grows in similar soil, aspect and topographic conditions as the restoration site, and provides primary habitat for koalas. If a healthy example reference site does not exist nearby, a model should be synthesised from local and regional records. This will inform the appropriate vegetation community composition, structure and function restoration targets for the project (Standards Reference Group, Society for Ecological Restoration Australasia, 2021).

Restoring a specific ecological community will not be attained simply by the presence of trees. It requires a range of species groups to drive processes such as nutrient cycling, water cycling, decomposition and pollination. These processes support the desired koala food tree-dominated stand to become ecologically functional and thereby persist into the long term in a similar manner to a naturally occurring plant community.

Species also need to be appropriate for the site so that they grow, reproduce and recover from environmental disturbances that may occur. An ecological community's dominant eucalypt species will differ in different regions, districts, sites and subsites; and the height, cover and spacing of trees will differ depending on whether the reference ecosystem is tall open forest (wet sclerophyll), open forest (dry sclerophyll) or woodland. However, desirable koala habitat usually has an open canopy and an understorey of grasses, other groundcovers and scattered shrubs.

4.2.2 Strategies for habitat restoration

The first principle in restoration is to protect existing habitat, even if it is individual mature trees. These areas then become the cores from which recovery can expand. Improved management of existing habitat, particularly if it shows signs of degradation, can lead to rapid recovery of highly suitable koala habitat.

Improved management and restoration of existing habitats is often attained through appropriate fire regimes and managing weed and pest animals. For example, forest favoured by koalas can be colonised by mesic (moisture requiring or rainforest-type) native and non-native species, particularly in higher rainfall areas with a long absence of fire. A simple approach to restoring or improving this type of habitat is to assess a site for evidence of fire exclusion and apply ecologically appropriate fire. When a site is less combustible, you may need to manually remove mesic vegetation before the appropriate fire regime can be feasibly returned. Whenever fire is used, follow-up weed management is required.

Planting and direct seeding are often needed to create new habitats because existing koala habitats have been extensively cleared and fragmented. This is particularly needed in locations and configurations that optimise the size and effectiveness of habitats for koalas.

Desirable restoration strategies could be to:

- protect existing koala habitat
- restore degraded koala habitat
- expand and link nearby existing patches of koala habitat through natural regeneration and/or revegetation
- revegetate extensively cleared areas to create new habitat patches, particularly through the creation of corridors and 'stepping-stone' habitat patches.

Different areas in the landscape will require different restoration approaches based on which threats are present. Where possible it is best to work outwards to expand existing habitat. Habitat connectivity is also important because an isolated koala population that is unable to disperse and breed with other populations is at risk of losing of genetic diversity, which can lead to lower resilience (Sherwin et al. 2000).

4.3 Priority areas

Priority areas for koala habitat restoration should be identified based on the:

- proximity to existing or declining koala populations (Rhind et al. 2014)
- strategic location with respect to connectivity and landscape-scale koala movement, particularly between conservation reserves, state forests, Aboriginal lands and Crown lands
- need and potential for fire and/or drought refugia
- presence of nearby remnant native vegetation
- quality, size and shape of existing koala habitat
- appropriate soil type, aspect, slope and water for the likely natural occurrence of koala habitat
- presence of permanent nearby sources of water, even if small, which can be relevant during dry periods and heatwaves
- current land tenure, land-use zoning, planning regulations and potential for in-perpetuity protection
- cultural importance of the site to Indigenous and non-Indigenous stakeholders
- effort required for restoration and maintenance.

4.4 How much habitat do koalas need?

To maintain a viable koala population, at least 40–60% of the landscape should be native forest or woodland for a 1-kilometre radius around where koalas occur, preferably dominated by high- and frequent-use koala habitat trees (McAlpine et al. 2007). Koala populations occur in areas with less vegetation, such as the Liverpool Plains around Gunnedah (Ellis et al. 2017). However, these populations are subject to greater impacts from a range of threats including exposure to heat and drought, dog attack and vehicle strike. Access to sufficient food and where needed, water, may also be restricted where there is less vegetation.

4.4.1 Patch size

Ideally, patches of habitat should be 50–100 hectares or more in size. If a habitat patch is smaller than this but well-connected to other patches (i.e. less than 100 metres apart) then the total area of the connected patches should be larger than 100 hectares

(McAlpine et al. 2007). Within this context, any small areas that landholders can contribute to a larger whole will help attain minimum habitat sizes.

Note that minimum patch sizes and home ranges may be lower or higher depending on habitat quality, rainfall region, degree of fragmentation and connectivity and the species of trees present. It is important to understand your local koala population and home ranges. Koala tracking studies in your area can help with this (e.g. Goldingay and Dobner 2014).

4.4.2 Patch shape

Habitat patches should be large enough to reduce edge effects that can lead to increased predation, influx of weeds and heat stress. Koala home ranges tend to be rounded (pers. comm.), allowing them to travel quickly between favourite trees. Koalas will also use wide corridors or patches that are square. Koalas appear to preferentially use high-productivity koala food trees growing along rivers and streams, but it is important that these are connected to or continuous with other habitat.

4.4.3 Connecting habitat patches

Increasing connectivity between existing koala habitat is essential. This can be done with corridors of vegetation preferably at least 20 metres wide, with appropriate openness to allow koala passage. Any increase in connectivity is valuable.

Narrow tree lines also have a place in habitat restoration. Tree lines can connect larger patches. When planted along waterways they provide valuable koala habitat (see section 4.5).

Koalas can easily move 100–200 metres between patches provided there are no barriers (e.g. roads, fences, buildings, water bodies, other structures) or threats (e.g. predators). On floodplains in northern NSW, female koalas have been known to travel more than 500 metres between koala food trees, across cleared grazing paddocks. Some tracked koalas have walked several kilometres cross-country (Lunney et al. 2012a). Although covering these distances is possible, they come at the cost of energy use and risk to the koala. Any reduction in distance between habitat patches provided by corridors or small stepping-stone patches can help koalas move more safely through the landscape.

Consider firebreaks to create connectivity and fire refuges for koalas.

4.5 How to address and minimise threats

Most koala populations live in fragmented habitat and many of these areas are subjected to ongoing pressures. Logging, clearing and fragmentation of habitat, vehicle strike, predation by domestic dogs and increasing exposure to wildfire are some of the major threats koalas currently face.

Koala habitat cannot be restored if factors that caused the degradation at a site remain. Where ceasing or mitigating threats is not entirely possible, minimisation of threats is important. When new habitat is being established, the site needs to be selected to avoid or minimise exposure of koalas to threats.

4.5.1 Road networks and fences

Koala death from vehicle strike is a significant contributor to koala population decline in certain areas of NSW. Roads also create barriers to movement and contribute to fragmentation of habitat.

Avoid planting koala food trees near main roads when restoring habitat (Lunney et al. 2012b). Instead, locate stepping-stone plantings to direct animals away from roads and known 'high strike' areas. When constructing new roads or obstacles, avoid putting them within and between koala habitat patches.

Fences can also create barriers to koala movement. Where there is a choice, avoid planting feed trees around fences or ensure fences are of plain wire.

4.5.2 Predation by dogs

Landowners should be aware of the risk dogs pose to koalas. Dog attack is a common cause of koala mortality, particularly in suburban and rural residential areas. Don't plant koala feed trees near locations where koalas would be at higher risk of predation. Where such risks coincide with existing koala habitat, dogs should be kept on leads where possible and be restrained at night. The document Protecting wildlife from domestic dogs (Department of Planning, Industry and Environment (DPIE) 2020) provides more information about how to reduce the incidence of dog attack on native wildlife.

4.6 Climate change impacts

Climate change is likely to be a significant stressor to koalas and their habitat (Figure 3). We all have a collective responsibility to reduce our carbon emissions and help mitigate climate change, and it is important to minimise carbon emissions when planning koala habitat restoration projects and programs.

As the climate becomes hotter, drier, and more variable, significant impacts on koalas may occur. Some of the likely impacts are listed in this section, along with recommended habitat restoration actions that may reduce those impacts.

4.6.1 Extreme heat events

Impact: Extreme heat events are likely to be more common with climate change and may cause heat stress for koalas and even death (e.g., Lemon et al. 2012).

Response: Ensure revegetation is linked to or includes dense shade tree species appropriate to the local ecosystem. Prioritise larger block plantings as these will be cooler on hot days than small-area plantings. Consider local microclimates, such as revegetating south-facing slopes, gullies and riparian sites if these previously supported eucalypt-dominated vegetation.

4.6.2 Changes to plant communities

Impact: Changes to plant community composition may occur and changes to plant community structure, including increased incidence of dieback, are likely with climate change.

Response: When including local provenance material in revegetation avoid collecting from mother plants within the same site as the planting. Instead, collect seed from widely spaced and multiple mother plants to ensure genetic diversity and optimise potential for adaptation. In addition, consider broadening the provenances to include a proportion of species from drier/hotter regions further north or west (Prober et al. 2015) and ensure donor and recipient

sites are well documented. Use tools like the NSW Flora: Ecological Niche Finder (Macquarie University 2021) or the Climate-ready revegetation guide (Hancock 2018) to inform your decisions. Trees from seeds with non-local provenance may become invasive or not survive. However, having diverse local genetics and a diverse mix of species and/or provenances may increase the likelihood that some will be palatable to koalas, as well as survive in future climate conditions.

4.6.3 Vegetation stress

Impact: Extreme heat events are likely to cause vegetation stress, which will potentially lower survival rates of plantings due to drought and hotter temperatures. These events can also potentially result in higher leaf toxicity and lower palatability for koalas.

Response: Good site preparation, initial and subsequent watering, and weed follow-up are critical factors to the long-term viability of plantings. If events causing vegetation stress are likely, consider breaking the project into smaller stages to accommodate the additional support required. Consider using local species of diverse genetic origin to increase the likelihood that some will survive future climate conditions and be palatable to koalas.

4.6.4 Changing eucalypt leaf nutrition

Impact: Eucalyptus leaf nutrition is likely to change with increased carbon dioxide in the atmosphere (Lunney et al. 2012a).

Response: Research is ongoing in this area. Currently there is no single solution to this issue. However, preferred koala food trees tend to be higher in digestible nitrogen, so planting more of these preferred species, accompanied by nitrogen-fixing species appropriate to the plant community, should result in more palatable trees.

4.6.5 Drier conditions

Impact: Koalas seldom drink water because they get enough from eating leaves. However, the presence of available water in koala habitat is becoming increasingly important, especially during dry periods and heatwaves.

Response: Plant or revegetate on soils with greater moisture availability (valleys, riparian areas) where eucalypts previously occurred (i.e. not in rainforest sites), especially in more arid regions, and plant near bodies of free water.

4.6.6 Increasing mesic colonisation of koala habitat

Impact: Colonisation of koala habitat by mesic native and non-native rainforest species occurs naturally, but often needs management if the aim is to ensure persistence of eucalypts as koala habitat (Ashton and Chinner 1999, Harvest et al. 2008, Stone et al. 2008, Horton et al. 2013). This process may be accelerated by increased atmospheric CO_2 (Bowman et al. 2010).

Response: Although access to tree species for shade and shelter will be increasingly important with climate change, avoid rapidly colonising rainforest trees within koala habitat plantings. Ensure appropriate fire regimes and weed management to maintain koala habitat in an open- rather than closed-canopied condition.

4.6.7 Sea level rise

Impact: Sea level rise may reduce available koala habitat in coastal areas.

Response: Consider planting on slightly higher ground. Identify priority revegetation areas to support landward migration of koala habitat on floodplains.

For more information on climate change and revegetation refer to Hancock et al. (2018) and Prober et al. (2015).

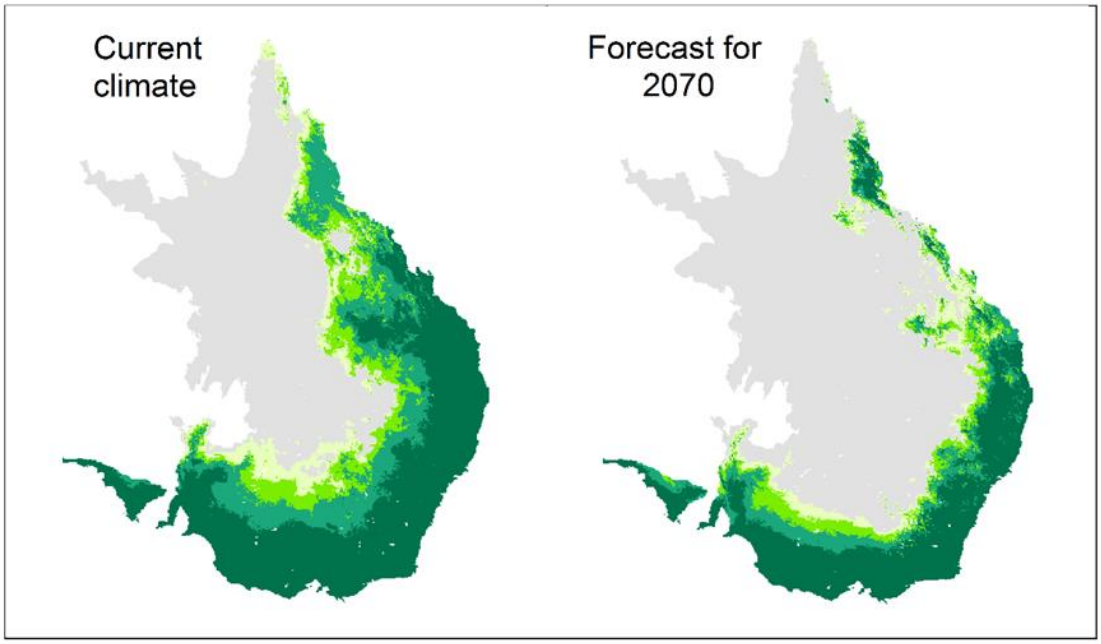

Figure 3 Predicted potential distribution of koala habitat under the current and 2070 climate predicted by Niche Mapper, based on energy and water requirements. This and other models in Briscoe et al. 2016 predicted a substantial decline in suitable koala habitat in central and northern inland regions by 2070. Dark green indicates highly suitable, lighter greens less suitable, and white/grey unsuitable habitats for koalas. Source: Briscoe et al. 2016

4.7 Fire management

Koalas live in bushfire-prone environments. Fire is a natural and important ecological process which maintains koala habitat because it:

- keeps habitat in an open state, enabling movement and migration of koalas
- is essential for maintaining forest health
- facilitates the regeneration of koala food trees.

High-intensity fires that burn the tree canopy can be fatal. Koalas can die directly through burns and smoke inhalation, or indirectly through starvation from temporary loss of food, dehydration, disorientation, or joey separation from mother.

Koalas can also be injured from falls or jumping from burning trees. Koalas that manage to escape a fire are likely to return to their original home range once trees start to regenerate.

Conversely, the long-term exclusion of fire, particularly in high rainfall regions, can result in a dense mid-storey that impacts eucalypt health and regeneration potential, and/or a shrub layer that can hamper koala movement. Carefully applied planned burns at an appropriate frequency and temperature, including cultural burns informed by Indigenous traditional

ecological knowledge relating to koala habitat, can help reduce high-intensity wildfire hazard, maintain open forest or woodland conditions, and reduce fire hazard to adjacent areas.

Where fire needs to occur in koala habitat, use low-to-medium intensity burns that avoid scorching the canopy to minimise impacts on koalas. Manual (e.g. raking) or mechanical (e.g. slashing) methods can be used in some situations to reduce fuel loads and/or maintain asset protection and firebreak zones. Some areas have detailed koala fire management guidelines, for example the Tweed Coast Koala Fire Management Plan (Baker 2016).

Ideally, areas with extensive koala habitat revegetation should be identified in bushfire asset registers and recognised in fire management plans.

4.8 Spatial data and mapping

Spatial prioritisation and predictive modelling are powerful tools that inform where to restore koala habitat (Adams–Hosking et al. 2011). This can be time-consuming, costly and relies on a very good understanding of local koala ecology, habitat mapping and threats.

Under the NSW Koala Strategy, the NSW Government funded a statewide Koala Habitat Information Base (DPIE 2019a). This database provides the best available state-wide spatial data on koala habitat, the likelihood of finding a koala at a location, preferred koala food trees and koala sightings for NSW. It is publicly available on the Sharing and Enabling Environmental Data portal (NSW Government 2021).

The database is helping to:

- protect koala habitat by supporting where to establish new koala reserves and private land conservation agreements
- ensure local actions are based on the best available information
- improve management of threats and disease.

5. How to restore koala habitat

Degraded koala habitat may have adequate koala food trees but may be unusable by koalas because high levels of weeds such as lantana (*Lantana camara*) prevent movement between trees. Restoring this type of habitat can increase habitat more quickly than creating new habitats.

Manual or chemical removal of undesirable species, or the use of fire plus follow-up removal of weeds, may be all that is needed to reinstate optimal functioning koala habitat. Ongoing planned burns, including burns informed by traditional ecological knowledge relating to fire and koala habitats, is important to maintain the health of these habitats (see section 4.7).

Degraded habitats that lack koala food trees, or don't have enough food trees, can be revegetated using 3 main approaches depending on the degree of degradation:

- natural regeneration
- facilitated/assisted regeneration
- reintroduction using seeds and/or seedlings.

The potential for regeneration of natives and weeds at a site is the first thing to consider when you plan to revegetate an area. This will help identify which revegetation approach, or combination of approaches, is best for a site.

Where natural regeneration is likely or can be facilitated, skilled interventions (see section 5.1) can be applied. Where it is evident that natural regeneration is unlikely, even after applying skilled interventions, revegetation using seed and/or seedlings will need to be informed by your site's size, soil type and the project budget.

Many fact sheets on revegetation techniques and materials exist, such as those published by Local Land Services, environmental organisations and Landcare groups. Contact local experts for advice relevant to your area. Not all techniques will work at all sites, so take the time to assess site conditions before you decide which approach to use.

5.1 Natural and facilitated regeneration

Natural or facilitated regeneration may be options where remnant native vegetation exists and even where isolated paddock trees or intact native topsoils alone exist.

Natural regeneration is the spontaneous resprouting of existing rootstocks or stems and/or germination of seeds from existing soil seedbanks or freshly dispersed by wind, birds or animals. It requires less effort and money, plants tend to develop strong root systems, and the site can develop a more 'natural' look compared to planted sites.

Wildlife friendly fencing (i.e. no barbed wire) to exclude animals that eat grasses and new seedlings may be all that is needed to promote natural regeneration in a site, as well as ongoing observation and ensuring appropriate structure and function of the site.

A natural regeneration approach can take time, especially if seed sources are distant from the restoration site. This approach may not occur if:

- there is insufficient bare soil and rainfall at the time of seed shed
- weeds hamper native regeneration
- local seeds or the existing seedbank are inadequate

Facilitated/assisted regeneration accelerates natural regeneration. It involves actively providing open niches for desirable species, and/or improving potential for their germination from the existing seedbank and/or naturally dispersing seed.

Removal of competing weeds can often trigger germination as it provides light to the soil and space for colonisation. For species that have seed stored in soil, such as wattles, the soil may need to be disturbed or fire introduced before germination will occur.

Eucalypts do not store seed in the soil but can colonise from nearby seed sources. To germinate, they require an exposed soil surface, relatively recent seed drop and above average rainfall conditions. Existing but suppressed eucalypt seedlings or saplings, can be released from competition using this method.

Facilitating natural regeneration requires:

- knowledge about local native plants and ability to distinguish natives from weeds at adult and seedling stages
- skills in weed control techniques
- familiarity with applying appropriate and timely soil disturbance and fire.

Consider these tips to facilitate natural regeneration:

- for sites dominated by exotic grasses or weeds with few or no natives, consider creating bare soil conditions for germination of a range of natives by:
    - scalping the weedy topsoil
    - treating the grass/weeds with herbicide before burning, followed by selective weed control to optimise native plant establishment
- for sites suitable for regeneration, reduce competition from exotic groundcover by selective spot-spraying weeds, and leave natives intact (Table 1)
- lightly cultivate soil around trees to promote suckering (the growth of new shoots)
- thin excessive tree or shrub density to attain a desirable open structure.

Any weed control, irrespective of restoration approach, must be followed by regular repeated visits to treat weeds. This is because the higher densities of weed that replace parent plants can leave a site in worse condition than before weed management. If this approach is followed a site will shift to an increasing healthy condition.

However, even with appropriate follow-up a facilitated regeneration approach may not be sufficient on its own if:

- the species that regenerate do not include species desired to establish the appropriate local community or koala habitat
- insufficient densities or genetic diversity are present
- trees and other vegetation do not establish exactly where they are needed.

In such situations, a regeneration approach can be combined with reintroduction of desired plants. This combines regeneration and reconstruction approaches to regenerate a site.

See Corr (2003) for more details about revegetation techniques for native Australian plants.

5.2 How to reconstruct good quality koala habitat

Habitat patches can include a range of koala food trees to meet medium-term habitat restoration goals. At least 30% of canopy trees in a habitat patch or corridor, depending on size of the patch, should be preferred koala food trees of a range of ages. Patches should also contain a range of other native trees and shrubs to provide shelter. However, the long-term goal should be to reinstate an appropriate native ecosystem based on locally occurring koala habitats to ensure the habitat persists.

Reconstructed habitat should have an open canopy and an understorey of grasses, ferns and scattered shrubs. In high rainfall regions, rainforest trees should be avoided in koala

plantings as they compete for light, moisture and nutrients, can smother plantings and in some areas encourage bell miner associated dieback. Rainforest shrubs may occur naturally in wet open forests and should be allowed to migrate naturally into plantings once koala feed trees are well-established.

5.2.1 What species to select

To produce a flourishing and self-perpetuating ecosystem when you revegetate, take the following steps to ensure you have selected suitable species:

- identify the appropriate local reference ecosystem (i.e. model community) for the site
- plant or direct seed the site's likely dominant species, including preferred koala food tree species for the area, to ensure stand sustainability
- plant other local native species consistent with the likely pre-existing community to meet short-, medium- and long-term habitat restoration goals.

The best way to work out the ideal composition for revegetating in terms of diversity and type of tree species (i.e. reference ecosystem), is to look at nearby forests that occupy a similar climate, geology, topography and aspect where there are also healthy koala populations. Then, taking environmental change into account, use those examples to guide your selection of tree and other species, and appropriate densities for revegetation. If there are no koalas nearby, the site may be more suited to a different ecological community, such as rainforest or wetland, which may be under threat and therefore depleted within the area – and may be the preferred restoration target for the site.

Koalas can live in many different forest types and often move between them for food and shelter. In some areas, forests are dominated by one or two preferred eucalyptus species and koala populations do well in such habitat. In other areas, forests are more diverse and local tree species may be less palatable, but koalas will survive by eating a varied diet and benefit from the diversity. Revegetating with a range of different species can reduce the risk of dieback, plant toxicity and seedling death.

Select koala food tree species with particular emphasis on the dominant species of the likely pre-existing community, taking future climate into account. Non-local food trees may be needed in the short term, but add these in a much lower proportion as they may not reproduce on the site. Match species to the moisture and fertility gradients on the site. Plants grown in unsuitable locations or where a species is not matched to site conditions may die or suffer nutrient and/or moisture stress, producing chemicals that discourage koalas from eating them.

A mix of trees, shrubs and groundcovers is important for ecosystem functionality and the long-term viability of the site. For example, include wattles for nitrogen fixing as well as other shrubs and groundcovers to support colonisation of burrowing fauna and decomposing organisms, particularly if the site is separated from remnant vegetation. Substantial proportions of native shrubs and groundcovers can also help to space trees at more appropriate densities for koalas.

Koalas benefit from access to shade and shelter trees that may not be koala food trees. In open forests (dry sclerophyll) in high rainfall regions, avoid using rainforest species for this purpose so as to reduce the potential of these species to shade out other species and prevent recruitment of eucalypts. In tall open forests (wet sclerophyll) adjacent to rainforests where rainforest species may form part of the community, allow rainforest species to migrate naturally onto the site once koala food trees have established. Aim to maintain the area as a tall open forest for long-term sustainability of the koala habitat.

5.3 Planting

Planting seedlings is usually more expensive than direct seeding because it involves more labour, time and money. Planting may be the preferred method of revegetation because it:

- gives greater control over the species mix, density and placement
- gives a more immediate impression of success
- is more efficient if seed is scarce
- can involve the community, which has important associated social and educational benefits.

There are many factors to consider when planting and establishing new seedlings to ensure they have the best chance of survival (Table 1). For example, site preparation is a critical part of establishing new seedlings. A well-prepared site will:

- reduce competition from grasses and weeds
- help build soil moisture
- provide the best opportunity for moisture and rain to infiltrate the soil
- allow for rapid and healthy root development.

Site preparation will be even more important given the anticipated impacts of climate change – as will be ongoing management of weeds to optimise establishment of desired species.

Care needs to be taken to attain the appropriate endpoint density of eucalypts so that they are not too close or too widely spaced. Densities may need to be higher initially to accommodate establishment failures, particularly in dry areas or years. In forestry, higher densities are often used to force taller growth earlier. If you use this technique be prepared to thin the planting after a few years to attain the appropriate density. If density is needed to enhance weed management alone, consider interplanting eucalypts with a wider range of other species (particularly shorter-lived wattles and perennial ground covers) appropriate to the community.

Table 1 Steps to consider when planting and establishing new seedlings

Planting process			
Step	**Method**	**Why**	**When**
1. Weed control	• varies depending on weed type and intensity • there are several options including chemical, fire-assisted, mechanical, manual and biological methods • consult the NSW Weed Control Handbook (Department of Primary Industries 2018) for more information on weed control methods, chemical use and withholding periods	• weeds compete for light, moisture and nutrients and can smother plantings	• early enough to allow 1–3 treatments before planting, depending on weeds • wetter/more productive areas will require weed control closer to the time of planting

Planting process			
Step	**Method**	**Why**	**When**
2. Animal control	• control or eradicate feral animals, e.g. rabbits • exclude livestock by using wildlife friendly fencing • deter native browsing animals by using wildlife friendly fencing or tree guards	• animals can eat and destroy seedlings	• before planting
3. Soil preparation	• ripping/deep tillage of soil (30–60 centimetres deep) • augering/drilling holes	• breaks up hard or compacted soil • increases soil moisture and rainfall penetration, which facilitates faster root development in seedlings	• rip soil preferably 4–6 months, minimum 1–2 months, before planting • augering should be done closer to planting time to reduce moisture loss
4. Source seedlings	• use local species, ensuring sufficient genetic diversity within the local genotype, but also investigate including different genotypes of these species (see section 4.5) • ensure good quality stock • commonly used pot sizes are Hiko cells and forestry tubes, established trees are also an option	• to ensure climate-resilient plantings • choice of pot size depends on budget and likelihood of plant survival	• source plants several months before planting • large orders may need to be placed a year in advance
5. Planting	• by hand (mattock, spade), or using tree planting tools, or tree planting machines • water plants well on the day of planting • tubes can be soaked in water but ideally water holes before seedlings are	• method depends on budget and resources available • watering removes air pockets around roots and minimises transplanting shock	• varies with region, but usually autumn, winter and spring (not summer unless well-watered)

Planting process			
Step	**Method**	**Why**	**When**
	planted to optimise survival • plant spacing is variable (see koala management area revegetation fact sheets, section 3.1) • delay planting if too dry		
6. Tree protection	• the whole site or area being planted can be fenced, but this can be expensive • a variety of tree guards are available, with varying costs, for example, carton/cardboard, corflute and wire/plastic mesh guards. • browse deterrent may be an effective and cheap alternative	• select type of protection depending on browsing pressure, budget available to install and remove, biodegradability and position in the landscape	• during planting
7. Extras (optional)	• mulch • weed mat • fertiliser/liquid seaweed • water crystals	• can improve the success of planting, but depend on cost, time and effort it takes to install/apply them	• during and after planting
8. Maintenance	• weed and animal control • remove tree guards once plants are tall enough • water plants if needed in summer of the first year • remove and replace dead plants if you have extra stock	• will enable the highest success of plantings	• after planting and as needed for a minimum of 1 year or until competition from weed is no longer a problem

Planting process			
Step	**Method**	**Why**	**When**
9. Monitoring	• monitor plant survival	• ensure plant survival meets desired targets • to inform ongoing maintenance such as weed and animal control and additional planting	• after planting for a minimum of 2 years but allow capacity for ongoing monitoring to support adaptive management if resources allow

5.4 Direct seeding

Direct seeding is a cost-effective and efficient technique, particularly for large-scale projects. Direct seeding is less suitable for some sites. Areas with heavy clay soils may have low germination rates and very rocky sites may prevent use of machinery. Sites with highly competitive, dense grasses may also be unsuitable for this method. Direct seeding has been widely used in some regions and has not been trialled in others. Check with your local natural resource managers about the use of this method in your region.

As with planting, site preparation is a critical part of direct seeding to reduce weeds that compete with germinating seedlings for moisture, light and nutrients (Table 2). Site preparation will be even more important given the anticipated impacts of climate change.

Table 2 Steps to consider when planting seeds directly into soil

Direct seeding			
Stage	**Method**	**Why**	**When**
1. Weed control and site preparation	• varies depending on weed type • there are several options including chemical, fire-assisted, mechanical, manual and biological methods • consult the NSW Weed Control Handbook (Department of Primary Industries 2018) for more information on weed control methods, chemical use and withholding periods • spray weeds or scrape soil in lines 1–1.5 metres wide and 4–5 metres apart	• weeds compete for light, moisture and nutrients and can smother plantings	• for best results spray twice during active growing seasons, e.g., once in autumn (6 months in advance) and once in spring just before seeding

Direct seeding			
Stage	**Method**	**Why**	**When**
	• good site preparation is important		
2. Animal control	• control or eradicate feral animals (e.g. rabbits) • exclude livestock by using fencing • deter native browsing animals by using wildlife friendly fencing	• animals can eat and destroy new seedlings, for example rabbits can be very destructive and eat all traces of germinated seedlings	• before planting
3. Seed	• select local koala tree and shrub species • try a mix of different provenances (i.e. genetically diverse local provenance, plus some from hotter/drier areas)	• climate-proof revegetation	• source seed and secure a seeding operator 2–12 months in advance
4. Direct seeding	• technique varies depending on site condition and type of seeder machine (including drones) used • ask your local experts • create seeding lines along contours or across the slope of land to reduce soil erosion	• direct seeding operators and resource managers will know the best seed rates and species ratios to use for your area • they also know how to calibrate seeder machines	• areas with high to moderate rainfall and/or frost: spring • semi-arid areas: autumn–winter
5. Maintenance	• weed and animal control	• enable high rates of seedling establishment • thinning may be necessary to meet desired stem density per hectare	• after planting (minimum 3 years)
6. Monitoring	• monitor germination and seedling establishment rates over a few years • most seedlings come up within 2–3 years	• ensure plant germination rates meet desired targets and assess which species germinate well at the site • direct seed a second time or do infill planting if seeding is unsuccessful	• after planting, minimum 3 years or until competition from weed is no longer a problem

6. Recording and monitoring restored koala habitat

The success of a restoration project is important to share with others to encourage similar actions and disseminate lessons learned. Demonstrating success requires evidence that shows changes on the site over time, including the site's initial condition. Monitoring based on reliable observations and record-keeping is important to the collective effort to restore koala habitat.

Monitoring by rural landholders and community groups will be less complex than the level of monitoring needed by agencies or publicly funded projects. The former may include photo-point monitoring, species lists and plant numbers, whereas the latter may require additional quantitative sampling or extend to using drone technology and advanced analytics to monitor plant survival and canopy cover. Regardless of the complexity of the monitoring, it is essential all projects document:

- contact information
- location, areas, dates and quantities
- starting condition of the site
- type/s of treatments applied
- changes over time.

Box 2: Koala habitat restoration platform

DPE has established regional koala habitat restoration projects to document and monitor koala restoration work throughout the state. Each project is hosted on the Atlas of Living Australia (ALA) BioCollect Projects platform Habitat Restoration NSW, which provides open access, web-based data collection and storage. This enables landholders and community groups to lodge information via online forms. Monitoring records can be added as they are collected.

DPE provides training for landholders and community groups to upload data to the platform.

For more information email: koala.strategy@environment.nsw.gov.au

The 2 main reasons to monitor koala habitat restoration projects are:

1. Vegetation monitoring to assess:
- initial plant survival/germination and establishment
- attainment of vegetation community structure over time.
2. Koala monitoring to detect:
- koala presence/absence
- koala activity and/or breeding.

6.1 Vegetation monitoring

Plant survival (for seedlings) or germination and establishment (direct seeding or regeneration projects) should be monitored in a systematic and unbiased way to:

- test whether treatments worked
- identify whether further maintenance or replacement treatments are required.

Baseline monitoring should be undertaken before or at the start of the project. The same scoring system should be used in subsequent monitoring. Monitor every 6 months over the first 2–3 years after treatment and then each year, or on an as-needs basis, after the first 2–3 years. Monitoring by landholders and community groups can be simple and easy, as described in the Checking for Change approach (Stol et al. 2016).

Consider these monitoring tips:

- For tree plantings, unless a site is small enough to count each plant, sample the plantation area using at least 6 randomly selected plots or transects. This is the minimum number required for statistical analysis. The size (e.g. 5 × 5 or 10 × 10 square metres) or length of the transects (e.g. 20–30 metres) will depend on the size of the site being sampled. Sample in areas of comparable soil/aspect/elevation.
- To monitor germination of trees and shrubs from direct seeding or regeneration, count germinating seedlings in at least 6 randomly selected plots in comparable areas. If the site is large, establish random transect lines and count the number of seedlings immediately beneath the line. This transect method is called a 'line intercept'. The length of transects (e.g. 20–30 metres) will depend on the size of the site.
- For groundcovers, plots can be smaller because the plants are smaller. Alternatively, you could use the 'step-point method' where you take 100 steps within each area or plot in comparable areas and count only what your toe touches (i.e. bare ground, rock, litter, native plant or non-native plant). Record the sum for each group or, for more powerful information, the individual species.
- Permanently mark the location of your plots or transects with a non-combustible peg and record its coordinates where possible. This will allow you to return to monitor at the same locations over time and record changes.

You can also record an index of plant health and/or plant height when evaluating plant survival in the revegetated area. The Australian Network for Plant Conservation's Guidelines for the Translocation of Threatened Plants in Australia provides more guidance on evaluation of plants (Commander 2018).

Informal descriptions of the structure of the native revegetation can be made each year to identify whether the vegetation community is developing in accordance with target spacing, height and girth of trees relative to mid- and ground-storey strata.

Photo-point monitoring, or taking photographs at a particular location, to record and monitor changes in plants over time is an effective way of monitoring and communicating the success of revegetation works. This can be done on the ground within plots and transects or from particular vantage points. For example, looking down on a site from an elevated position or using drones flying at the same height and angle each year, which can be useful as the view from flat sites can be blocked by the front row of plants over time. Make sure you have multiple photos that show the starting point of your project because some photo-points will work out better than others over time.

6.2 Koala monitoring

The NSW Koala Monitoring Framework is designed to facilitate and coordinate monitoring across a range of spatial scales (i.e., local, regional and statewide), and also provides general guidance on monitoring the effect of conservation actions (Department of Planning, Industry and Environment 2021).

There are many ways to monitor koala presence/absence and density to determine whether koalas are occupying remnant and restored habitat. These include:

- **Faecal pellet surveys** search an area for koala scats to infer the presence/absence of koalas and koala activity. There are many scat survey methods, the most commonly used are:
    - Spot Assessment Technique (SAT) consists of a variable radius plot in which the litter within 1 metre of the trunks of the nearest 30 live trees is searched for koala faecal pellets (Phillips & Callaghan 2011).
    - Regularised Grid-Based Spot Assessment Technique (RGB-SAT) involves survey sites located at grid-line intersections at defined intervals (350 metres, 500 metres or 1 kilometre). The presence/absence of koala faecal pellets is assessed using the SAT method at each site. This method is powerful when repeated at the same survey sites over several years (Phillips & Hopkins 2008).
- **Dog surveys** involve detection dogs trained to detect the scent of koalas and/or koala scats (Cristescu et al. 2015). Although dogs can be more effective than humans at detecting koala scats, their ability to detect koalas can be limited.
- **Radio- or GPS-tracking** follow the movement of koalas using radio- or GPS-tracking devices. Radio or GPS devices are attached to individual animals and used to understand home ranges, habitat use and connectivity (Davies et al. 2013; Crowther et al. 2014; Goldingay & Dobner 2014). These methods are undertaken by licensed wildlife researchers.
- **Systematic nocturnal spotlighting** involves walking a specified path at night using a bright torch or spotlight to look for koala eyeshine (Smith 2004; Wilmott et al. 2018). Limitations to this method include missing koalas when they are not facing the spotlight, when they have conjunctivitis, or in areas with dense canopy.
- **Acoustic recordings** involve setting up a small recording device in the field for extended periods to record male koala calls or bellows. It is most effective in the peak of the koala breeding season (September to December; Law et al. 2018). Acoustic monitoring is used to estimate occupancy (presence/absence) and methods are being developed to estimate density using acoustic arrays.
- **Thermal imaging from drones** is rapidly becoming more sophisticated, cheaper and more versatile. Thermal imaging currently relies on a temperature differential between the koala and ambient temperatures, which means it works best at cooler times of the day and in cooler seasons. This method can be used to estimate koala density at a site.
- **Sightings reported by landholders or members of the community** can be a valuable source of information. Download the ‘I Spy Koala’ app to your phone or tablet to record sightings of koalas in the wild. Sightings are uploaded to the BioNet Atlas (NSW BioNet 2021a). Alternatively, koala sightings can be sent to BioNet directly. There are also many koala citizen science projects registered with BioNet. Some local councils record koala sightings on their websites.
- **Sightings of mothers with joeys** are a good indicator of long-term habitat restoration success because it indicates that the habitat is able to support a breeding population.

7. Case studies

These case studies provide examples of koala habitat being successfully created, restored and/or enhanced across some of the koala management areas (KMAs; see section 3.1) identified in NSW.

Case study 1: Monitoring Koalas on the Tweed Coast (KMA 1)

Context: Koala habitat on the Tweed Coast in north-eastern NSW is extremely fragmented. Patches of eucalypt forest or woodland large enough to sustain a viable koala population are restricted to areas between Kingscliff and Pottsville. The koala population in this area is listed as endangered. Tweed Shire Council has been implementing programs to protect koalas and improve their habitat for many years. The Tweed Coast Koala Plan of Management (KPoM) was adopted in 2015. Since then, Council has partnered with community organisations to plant 54,720 trees, providing 44.68 hectares of new koala habitat. They have also implemented other recovery actions such as purchasing land to protect koala habitat and creating koala zones to reduce vehicle strike. To assess whether the Tweed Coast KPoM was having an impact, Council implemented a rigorous monitoring program.

Aim: To understand changes in koala distribution, activity and occupancy within the Tweed Coast area between 2010 and 2018.

How: Koala scat surveys used the Regularised Grid-Based Spot Assessment Technique (see section 6.2). Permanent monitoring sites were established in a regular pattern of about 600-metre spacings. Survey sites were marked to ensure consistency through time. Surveys were conducted in 2010, 2015 and 2018; before, during and after the introduction of the Tweed Coast KPoM.

Results: Koala activity and distribution on the Tweed Coast declined substantially between 2010 and 2015, and increased in 2018 in some of the areas that were vacant in 2015. This suggests that some recovery and reconnection of populations has occurred.

Figure 4 Heat maps showing changes in the intensity and the distribution of koala activity in the southern portion of the Tweed Coast between 2010 (left), 2015 (middle) and 2018 (right). Lower koala activity is indicated by blue shading, grading through red with yellow representing areas of highest koala activity. Yellow dots represent the locations of 56 sites that were surveyed in all 3 years. Source: Tweed Coast Koala Study 2018

In the southern portion of the Tweed Coast, a relatively stable resident population continues to persist in good quality habitat in the Pottsville Wetland (Figure 4). In the adjacent northern portion, the distribution and intensity of koala activity fluctuates over time.

Encouragingly, two-thirds of monitored koala habitat planting sites have been used by koalas. Many sites were used within 2.5 years of planting.

The koala population on the Tweed Coast remains unstable, small, fragmented, and at an occupancy rate that is well below sustainable. Continued monitoring (every 3 years) is vital to understand long-term koala population trends in the area.

Key messages:

- Following a rigorous, repeatable survey method across a region is a powerful way to understand changes in distribution and activity of a koala population.
- Through the implementation of threat abatement, recovery actions and development controls in the Tweed Coast KPoM the Tweed Shire Council and the local community are working towards the long-term protection of the Tweed Coast koala population. Continued population monitoring is essential.

More information: Tweed Shire Council

References

Scott Hetherington (Senior Program Leader for Biodiversity, Tweed Shire Council), 2021, pers. comm.

Tweed Shire Council 2015, Tweed Coast Comprehensive Koala Plan of Management 2015, Tweed Shire Council, Murwillumbah, NSW.

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Case study 2: Tree Parents Project, Bongil Bongil National Park (KMA 1)

Context: Bongil Bongil National Park is a 4300-hectare conservation reserve located 20 kilometres south of Coffs Harbour on the NSW north coast. The national park is renowned for its large koala population and provides high-quality habitat for an estimated 400 koalas. However, a significant proportion (around 660 hectares) of the park is occupied by even-aged stands of native eucalypt plantation species, such as blackbutt (*Eucalyptus pilularis*) and flooded gum (*E. grandis*), that were planted in the early 1970s. These plantation species, although native to the NSW north coast, are not preferred koala food trees. The understorey of many of these plantations is now dominated by the weed species lantana (*Lantana camara*) and broad-leaved paspalum (*Paspalum mandiocanum*).

Aim: To convert 20 hectares of degraded eucalypt plantation within Bongil Bongil National Park to primary koala habitat using 10 teams of volunteers planting and nurturing 600 koala food trees for 3–4 years.

How: The NSW National Parks and Wildlife Service (NPWS) received funding through the former Office of Environment and Heritage (OEH) Volunteer Grants Program. The project gathered 10 teams of volunteers from the local community. Each team was allocated 2 hectares and 60 preferred koala food trees to plant and manage.

Tree species planted included tallowwood (*E. microcorys*), grey gum (*E. propinqua*), swamp mahogany (*E. robusta*) and forest sheoak (*Allocasuarina torulosa*). Each team was given tools, water and personal protective equipment to use when planting and maintaining their block. Plants were protected with wallaby-proof wire cages. Several years before planting, lantana was removed systematically by NPWS staff using splatter gun, hand pulling, cut, and paint- and spot-spray techniques.

NPWS trained the volunteers and supported them over 3–4 years to be good ‘tree parents’ by encouraging accountability, teamwork, experiential learning and competitiveness. Trophies were presented to teams with the tallest trees and highest plant survival.

Results: After 12 months, 96% of plants had survived. Dead plants were replaced and this increased the survival rate to 100%.

The plants grew quickly. The tallest tree (swamp mahogany) reached almost 3 metres height in 12 months (Figure 5).

Within less than a year, a koala and joey were frequently sighted in remnant trees inside a planting block. Koalas are now regularly seen on the restoration site.

The program was so successful it was repeated in 2017 and another 600 koala trees were planted by volunteer tree parents. The survivorship of plants after 18 months replicated the 2015 results of 96%.

Figure 5 The winning swamp mahogany, grown by the 'Roos' in Block 7, almost 3 metres high at 12 months of age. Photo: Martin Smith/NPWS Coffs Coast Area

Key messages:

- Competitiveness of volunteers, supportive management and recognition of their dedication through awards can lead to high plant survival and growth rates.
- Good site preparation, weed control, protection from browsing animals, and follow-up maintenance can lead to excellent results.

More information: NPWS, Coffs Coast Area

Phone: 02 6652 0900 or email: info@environment.nsw.gov.au

References

Martin Smith (NPWS senior ranger), 2019, pers. comm.

Martin Smith 2016, The Tree Parents Project, Bongil Bongil National Park, Project Review: The First Year 2015–16. NPWS, Coffs Coast Area.

OEH 2017, Volunteers invited to compete in local tree planting project to save koalas, Media release: www.environment.nsw.gov.au/news/volunteers-invited-to-compete-in-local-tree-planting-project-to-save-koalas

Case study 3: Coffs Harbour & District Local Aboriginal Land Council (KMA 1)

Context: This project is based on a Coffs Harbour and District Local Aboriginal Land Council (CH&D LALC) property at Mylestom, 24 kilometres south of Coffs Harbour on the north coast of NSW.

The Mylestom block is bounded to the north by Bongil Bongil National Park and to the south, east and west by Crown Land. The block has exhibited evidence of a koala population through various flora and fauna surveys undertaken in the past few years. Surveys have identified valuable habitat and animal food sources on the property including mature core koala habitat tree species such as tallowwood (*Eucalyptus microcorys*), grey gum (*E. propinqua*), brush box (*Lophostemon confertus*), forest red gum (*E. tereticornis*) and white mahogany (*E. acmenioides*) trees.

The CH&D LALC has dedicated koala management actions within the CH&D LALC's Natural Resource Management Plan (2020–2025) for the Mylestom block.

The koala is culturally significant to the Gumbaynggirr people who are traditional owners of the mid-north coast region. It features as a law-maker in Gumbaynggirr creation stories. These socio-cultural ties ensure that Gumbaynggirr people retain a sense of respect, obligation and responsibility to protect koala populations and effectively manage and sustain core koala habitat. Gumbaynggirr worldview and cultural values situate threatened species challenges holistically – if Country is unwell then so is everything within it. Actions to protect koalas are intrinsically tied to effective land and natural resource management of the area as well as areas connected in geographic and culturally significant ways.

Aim: To effectively manage the health and wellbeing of Country including core koala habitat through the application of traditional ecological knowledge, cultural practices, community involvement and the environmental protection, improvement and expansion of existing koala habitat areas.

How: Inform and determine actions by increased mapping and data collection, cultural revitalisation practice and identifying threats to koalas, including loss, modification and fragmentation of habitat and intense bushfires that scorch or burn the tree canopy. Key actions include:

- Flora and fauna surveys and cultural site inspections undertaken in partnership with the Nature Conservation Council and completed in 2018.
- Community involvement and the reintroduction of the Koala Dreaming Story to the site, including intergenerational knowledge transfer, undertaken in May 2020 in partnership with Bularri Muurlay Nyanggan Aboriginal Corporation.
- Initial cultural burns and understory weed clean-up in July–August 2020, with follow-up weed treatment and cultural burning of unburnt areas in August 2021 (Figure 6).
- The planting of 300 core koala and flying fox habitat trees, plant stocks, stakes and guards suitable for the extension of identified canopy area in October–November 2020 and follow-up care and weeding in February 2021.
- Ongoing vegetation management, reviews for cultural burning every 6 months, onsite training and up-skilling opportunities.
- Koala scat identification in koala habitat zones using trained sniffer dogs to inspect burnt and unburnt areas (cultural fire impacts), in September–October 2020. This project was undertaken in partnership with the Jaliigirr Biodiversity Alliance and Canines for Wildlife with support from a Transgrid Community Partnership Grant.
- Ongoing pest management monitoring, onsite training and up-skilling opportunities.
- Ongoing monitoring of native flora and fauna, onsite training and up-skilling opportunities.

Results:

- Flora and fauna mapping and koala scat surveys identified key koala habitat and evidence of occupation.
- Monitoring by the Durrunda Wajaarr Team recorded a survival rate of 75% of 275 planted trees. As per the Mylestom Plan of Management, the CH&D LALC team will maintain the planting area for the next 3 to 5 years at 6 monthly intervals. Plant growth rates and condition will be monitored over this time.
- Regrowth from grasses including bladey grass (*Imperata cylindrica*) and kangaroo grass (*Themeda triandra*) occurred within 2 weeks of conducting the cultural burn. An increase in plant

health was observed within weeks of administrating the burn. Soil health is important to koala habitat.A key result of the burn was the establishment of an enriched soil profile that is diverse in slow- and fast-acting minerals to allow for a diversity of culturally and ecologically important plant species to grow and support a healthy ecosystem.

- The application of cultural fire in key koala habitat has also reduced fuel, reduced the threat of wildfire and reduced ground surface debris in-turn easing the navigation for koalas over the landscape.

Figure 6 Darrunda Wajaarr ranger Narina Ferguson undertaking cultural practice at the Mylestom Block. Photo: Thunderbox

Key messages:

- Ongoing monitoring and data collection activities will be guided by koala management actions in the CH&D LALC's natural resource management plan for the Mylestom block.
- CH&D LALC's koala management activities are considered culturally significant, culturally safe and informed, and are grounded in an overall vision and plan to protect, cultivate and sustain the health of Country.
- It is important to involve community in threatened species management actions. Cultural revitalisation and re-activation practices will help increase and sustain community involvement in reducing threats and achieving positive outcomes for koalas.
- The CH&D LALC enjoys working with various partners and looks forward to future collaborations in koala conservation and caring for Country practice.

More information: Coffs Harbour & District LALC

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Case study 4: Koala connectivity corridor in the Cumberland Plain (KMA 2)

Context: The Cumberland Plain woodlands once covered 107,000 hectares of the western Sydney Basin. Only 6500 hectares, less than 6%, of the woodlands remain in small fragments surrounded by agriculture, housing and industry. Key koala habitat in the southern section of the Cumberland Plain has been significantly degraded, especially the mid- and ground-storey. Connection between koala habitat areas has also been impacted and remaining fragments are under intense pressure from urban development and weeds. Despite this, there is some evidence that koala numbers are slowly recovering in the woodlands.

Aim: To restore 0.8 hectares of long-grazed koala habitat at Cook Park in Ruse using native trees, shrubs and grasses. To strengthen a key koala corridor between the Georges River wildlife corridor and Smiths Creek, Campbelltown's largest urban bushland reserve. This will allow safer koala movement within the landscape.

How: Greening Australia received funding from WWF-Australia for this habitat restoration project. Three-thousand seedlings were planted in 2019 in 3 separate events, including a large community planting on Wild Koala Day when over 100 volunteers planted 1500 plants (Figure 7). The remaining seedlings were planted during events with a local school, Bushcare volunteers and Greening Australia staff. A thick layer of mulch was also added to aid moisture retention and reduce weed competition. Most plants were groundcover species or shrubs (50 koala food trees were planted), because the existing canopy layer was relatively intact. Koala-friendly species were identified through consultation with experts from Campbelltown City Council.

Result: Koalas were sighted in remnant trees on the site within 1 year of restoration actions. At the time of writing, the plantings were in good condition.

Key messages:

- It is possible to restore and connect koala habitat by enhancing degraded remnants, even when land availability is limited.
- Working with local stakeholders, such as the local council who have knowledge and expertise is important. Campbelltown City Council identified this site as part of an important koala corridor.
- Engaging the community in revegetation events is an effective way of getting a large amount of plants in the ground in a short amount of time.
- Raising awareness about local koalas and making it easy for people to take action is important.
- It is important to make use of local knowledge, as local experts will know what tree species koalas prefer in each area.

Figure 7 Community planting event at Cook Park in Ruse. Photo: Greening Australia

More information: Greening Australia, Western Sydney Office

Reference

Courtney Sullivan, Greening Australia Restoration Ecologist, 2019, pers. comm.

Case study 5: Koala use of young Eucalyptus plantations on the Liverpool Plains (KMA 6)

Context: The Liverpool Plains are among some of Australia's most productive and fertile agricultural lands. This region has been substantially cleared for intensive cropping, grazing and most recently mining, resulting in a reduction of woodland cover by more than 90%. Rising soil salinity from land clearing triggered a revegetation program between 2001 and 2004, which resulted in 400 hectares of eucalypt plantations being established on private land. These plantings had the added benefit of providing potential habitat for native animals. Gunnedah and the Liverpool Plains are a well-known hotspot for koalas, but it was unknown whether koalas would use the new plantings.

Aim: To understand whether koalas (and other animals) would use young eucalyptus plantations on the Liverpool Plains, and what factors influenced their use.

How: Researchers from the NSW Department of Primary Industries recorded koala presence and absence at 43 study sites: 27 eucalypt plantations, 11 remnant patches of forest and woodland, and 5 paddocks. Surveys included daylight searches, spotlight surveys, camera trap records and scat surveys. Two koalas were fitted with GPS collars and tracked for 5–7 months.

Results: Koalas were more likely to be found in remnant patches than young eucalypt plantations. Koalas were recorded at 64% of remnant patch sites compared to 26% of plantation sites. No koalas were recorded in paddock sites. Koala presence or absence was strongly linked to the amount of mature remnant vegetation within 5 kilometres. Sites adjacent to large areas of remnant vegetation were more likely to be used by koalas.

Koalas used planted trees as young as 2 years old for foraging, particularly river red gum (*Eucalyptus camaldulensis*), and trees 4–7 years old for foraging and shelter (Figure 8).

The 2 tracked koalas often used eucalypt plantations, woodland patches and isolated paddock trees, and showed a slight preference for eucalypt plantations.

Figure 8 Koalas commonly used young trees in eucalypt plantations – this tree was about 2 years old. Photo: Helen Engel

Key messages:

- Young eucalypt plantations of preferred koala food tree species (*E. camaldulensis*) can provide valuable koala habitat, provided they are located close to large areas of remnant forest and woodland. Favoured koala food trees in the nearby Pilliga forests include other red gums
- (*E. blakelyi* and *E. chloroclada*) and the locally endemic Pilliga box (*E. pilligaensis*).
- A combination of remnant patches, plantations and scattered trees within the landscape provides a variety of complementary resources that koalas will use.
- Uptake and use of eucalypt plantations by koalas can be remarkably quick and extensive.
- Revegetation can help sustain a koala population and mitigate the impacts of habitat loss and fragmentation.

More information: Rod Kavanagh, Southern Cross University, Lismore

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Case study 6: Revegetation of high-quality koala habitat in the Wingecarribee Shire (KMA 2)

Context: Surveys conducted in the Wingecarribee Shire in 2017 by NSW Government staff estimated that over 3000 koalas reside in the region, making it the largest known population in southern NSW. Koala density is influenced by vegetation community type and condition. Within the region, higher koala densities correlate with higher soil fertility. A koala habitat restoration project in the Southern Highlands focused on 2 critically endangered ecological communities: Robertson basalt tall open-forest and Southern Highlands shale forest and woodland. These 2 vegetation communities support a relatively high density of koalas and are the highest quality koala habitat in the region.

Aim: To engage local stakeholders to restore 42 hectares of high-quality koala habitat (also endangered ecological communities) by planting 2500 trees, including koala feed trees.

How: Three sites within the Upper Nepean State Conservation Area that were high-quality koala habitat had been cleared for forestry plantations. The sites were in varying condition before planting, but typically had good natural regeneration of the ground cover and understorey. However, there was little regeneration of canopy species.

Plant species used to revegetate the sites were selected based on official listing advice for the 2 endangered ecological communities, that were formerly present, and expert knowledge. Only canopy species were planted. Due to dry conditions in spring 2018, planting was held over until autumn 2019.

Seedlings were sourced from local nurseries. Minimal spot-spraying of weeds was required due to the largely native groundcover. A hazard reduction burn at one site helped the planting process. Holes for seedlings were dug about 8 to 10 metres apart and water crystals added. Seedlings were protected with 800-millimetre-tall galvanised mesh tree guards because deer were active in the area. The seedlings were watered at planting and then monthly if conditions warranted. The land manager's ongoing deer control program included the revegetation sites.

Results: Preliminary results at the time of writing indicate a greater than 90% survival of seedlings. Monitoring at each site will include plant diversity surveys within fixed plots to understand the condition of the endangered ecological communities, recording seedling survival counts and, over the longer term, evidence of koala use (presence or scats).

Key messages:

- Good planning targets areas of high-quality habitat for restoration and/or areas that have high connectivity value.
- Good site preparation, protection of seedlings from browsers and follow-up maintenance achieves good results.
- Targeting areas with potential high habitat value, such as good quality soils, results in greater benefits to koalas.

More information: Department of Planning and Environment (DPE) Illawarra

Reference

Lachlan Wilmott, Threatened Species Officer, DPE Illawarra Region, 2019, pers. Comm.

8. Glossary

Browse deterrent: A compound applied to leaves of plants to make them non-palatable to herbivores such as cows or kangaroos and protect newly planted trees and shrubs from being eaten.

Direct seeding: Sowing seeds directly onto a site by machine or hand.

Facilitated/assisted natural regeneration: Approach needed to foster natural regeneration where it is not expected to occur spontaneously.

Local provenance species: Plant species or populations that contain local genetic variation. Local provenance plants are grown from seed collected from healthy plants growing near to and in similar conditions as the planting site. This gives the plants a better chance of surviving.

Mesic: A mesic habitat has a moderate or well-balanced supply of moisture; mesic species require moisture.

Natural regeneration: Recovery or recruitment of species from a germination or resprouting event.

Patch: An area of vegetation or habitat that differs from its surroundings.

Planting: Planting nursery-grown seedlings by machine or hand.

Preferred koala food tree species: Trees that koalas use for food as well as shelter and social activities. For further details see A review of koala tree use across New South Wales (OEH 2018a) and our koala management area fact sheets (see section 3.1). Other trees such as rainforest trees and non-native trees may be used by koalas for shade, but they do not feed in these trees.

Propagule: A vegetative structure such as a bud, sucker, or spore, that can detach from a plant and give rise to a new plant.

Restoration: The process of helping the recovery to a healthier condition of a species, population or ecosystem that has been degraded, damaged or destroyed.

Revegetation: Establishment, by any means, of plants on a site.

Riparian: A riparian area or riparian zone is the interface between land and a river or stream, such as a riverbank.

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Appendix: Engaging with Aboriginal communities

As part of the world's oldest living culture, First Nations peoples are owners and custodians of the Australian continent and adjacent islands. They share a unique bond to Country – a bond forged through thousands of years of occupying, managing and travelling across lands and waterways for ceremony, religion, trade and seasonal travel.

For First Nations peoples, Country takes in everything within the physical, cultural and spiritual landscape – landforms, waters, air, trees, rocks, plants, animals, foods, medicines, minerals, stories and special places. It includes law, kinship, cultural practice, knowledge, songs, stories and art, as well as spiritual beings, and people: past, present and future. First Nations peoples maintain a core belief that when Country is cared for the right way and is healthy, so is everything and everyone else.

Conservation practice is inherent within Aboriginal and Torres Strait Islander cultures. Their land management practices have been influencing and protecting biodiversity health for many millennia. These guidelines recognise the value and importance of working in collaboration with First Nations peoples to embed their place, roles and wisdom in koala conservation and management.

Koalas are of cultural significance to certain Aboriginal communities in NSW, engendering story, place, and law and kinship responsibilities to koalas and koala country. These relationships can play an important role in caring for koala populations across tenures and into the future.

When working to restore habitat on public lands in NSW it is important to consult with Aboriginal custodians/traditional owners; for example, through protocols provided in this document.

Protocols

Aboriginal communities within Australia and NSW are distinct and diverse. This means that local protocols will also be distinct and diverse. However, there are some general protocols that may help effective engagement and form meaningful partnerships, which is ultimately dependent upon building local relationships.

General principles that help build relationships with Aboriginal communities:

- acknowledgment of the diversity of Aboriginal communities and culture
- respect for Aboriginal peoples' relationships to Country
- value of traditional ecological knowledge and Aboriginal people as knowledge-holders and experts
- respect for Aboriginal cultural principles and protocols, including in relation to knowledge-sharing practices (Janke 1998)
- protection of ownership, copyright, and Indigenous cultural and intellectual property
- acknowledgment of the impacts of historic and ongoing trauma.

Ways to approach communities:

- Start engagement early in your project and find out about local protocols.
- Identify key contacts in your community to draw upon existing networks where possible and seek advice on any local cultural protocols to tailor your approach. These could include local Aboriginal land councils, native title traditional owner's prescribed bodies

corporate, Aboriginal land owners and management bodies, Aboriginal Elders and other community representatives, such as Aboriginal ranger groups.

- Engage Aboriginal stakeholders in the early stages with appropriate timeframes. Provide information before meetings to give people time to understand your project and involve the relevant people.
- Clearly articulate the purpose of engaging. Outline previous discussions and agreements with third parties, e.g. state agencies and other stakeholders.
- Allow time for Aboriginal peoples and individuals to decide whether they wish to become involved in the activity or project.
- Allow flexibility for alignment and changes to the process.
- Identify and adhere to processes or protocols that Aboriginal people have established for consultation (Australian Heritage Commission 2002). This includes protecting sensitive information disclosed during the process and processes for obtaining consent from Aboriginal peoples to display any information gathered, including publishing online, to avoid culturally inappropriate disclosure.
- Provide fees for service – Aboriginal knowledge is complex, specialised, and owned by Aboriginal peoples. Aboriginal stakeholders who choose to work in any capacity are entitled to be remunerated appropriately.

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