NSW GOVERNMENT | Biodiversity Conservation Trust

Biodiversity Conservation Trust Ecological Thinning Guidelines

For BCT agreements | November 2020

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Glossary

Term	Definition
Accredited assessor	A person accredited to apply the Biodiversity Assessment Method (BAM) and assess impacts on biodiversity at development sites and biodiversity stewardship sites.
Benchmark	A quantitative measure that represents the 'best-attainable' condition. Vegetation condition benchmarks are defined for specified variables for Plant Community Types, Vegetation Classes and Vegetation Formations in the NSW BioNet Vegetation Classification. Benchmarks that may assist determining whether ecological thinning may be appropriate include those related to cover and richness of plant growth forms (e.g. tree, shrub, grass, forb).
Biodiversity Assessment Method (BAM)	The BAM is a scientific document that outlines how an accredited person assesses impacts on biodiversity at development sites and stewardship sites (see DPIE 2020).
DBH	Diameter of a tree trunk at breast height (approx. 1.3 m)
Ecological thinning	The selective removal of individual native trees to improve or maintain the ecological value of an area.
Growth form	The form that is characteristic of a particular plant species at maturity. The broadest classification includes trees, shrubs, grasses and grass-like plants (e.g. sedges and rushes), forbs, ferns, and others (e.g. palms, tree ferns and vines) (see the BAM, Appendix F).
Plant Community Type (PCT)	A classification system for plant communities in the NSW BioNet Vegetation Classification.

Term	Definition
Private land conservation agreement	A joint agreement between the landholder and the Biodiversity Conservation Trust to conserve and manage biodiversity on an area of land. Includes Conservation Agreements and Biodiversity Stewardship Agreements.
Stem Density	Number of tree stems expressed as the number of individuals per 1000m^2 (0.1 hectare, 20m x 50m plot), measured for tree stem size classes: <5, 5–9, 10–19, 20–29, 30–49, 50–79, and 80+ cm at DBH.
Vegetation Class	A classification of the type of vegetation structure. Vegetation Classes are further classified into Plant Community Types within the NSW BioNet Vegetation Classification.
Vegetation Formation	A general NSW based classification of the type of vegetation structure. Vegetation Formations are further classified into Vegetation Classes within the NSW BioNet Vegetation Classification.

Objective

The NSW Biodiversity Conservation Trust (BCT) partners with landholders to conserve and manage biodiversity on private land by establishing conservation and biodiversity stewardship agreements. Biodiversity values at these sites are maintained, enhanced or restored using a range of management actions, agreed upon by you, the landholder, and the BCT.

Ecological thinning is the selective removal of individual native trees to improve or maintain the ecological value of an area. Ecological thinning has been identified as a potential management action that may be considered under certain circumstances in specific ecosystems. In some ecosystems, ecological thinning may support biodiversity by allowing retained trees to mature more quickly, improving stand age and species complexity, increasing ground cover including native understorey and coarse woody debris, and improving habitat for an increased diversity of species.

The objective of these guidelines is to provide landholders with a broad understanding of ecological thinning in the context of biodiversity conservation and management. They provide a list of principles and circumstances for when ecological thinning may be appropriate and provide you with a range of options for applying ecological thinning to achieve conservation outcomes. You can use these guidelines to help determine if ecological thinning is appropriate as a management action to improve biodiversity at your site.

These guidelines are based on current scientific understandings of ecological thinning as an active management action for promoting or enhancing biodiversity in specific ecosystems. Acknowledging that each site presents unique circumstances, these guidelines should be used as a framework that can then be tailored to a variety of situations. These guidelines acknowledge that the scientific understanding of ecological thinning is still limited. Regular monitoring, as part of a long-term adaptive management strategy for evaluating conservation outcomes from ecological thinning, will be essential to help guide decision making.

These guidelines do not endorse ecological thinning as a management action appropriate for all ecosystems or for all conservation agreement and biodiversity stewardship sites. The BCT will support ecological thinning in cases where there is a clear ecological objective and where evidence exists to support the approach. Where determined to be an appropriate management action, ecological thinning is permitted by the BCT through a special condition in the conservation agreement. Thinning to promote productivity (e.g. to enhance pasture growth for stock), or to promote forestry outcomes (e.g. encouraging trees to grow quickly for future harvest) will not be supported.

If you are seeking to implement ecological thinning as a management action for your site agreement, you must use these guidelines in consultation with BCT staff or a BAM accredited assessor to determine whether they may be appropriate for your site.

Introduction

Ecological thinning can be defined as the selective removal of individual native trees to improve the ecological value of an area. To distinguish ecological thinning from commercial thinning such as that for farming or forestry practices, we propose that:

> *'The purpose of ecological thinning is to reduce competition between trees or shrubs to allow growth and maturation of the remaining trees and shrubs; regeneration of trees, shrubs and ground cover; and growth of ground cover; thus improving vegetation composition and structure'*
>
> (adapted from the Environmental Outcomes Assessment Methodology, NSW Government 2013).

Why could thinning be useful?

During the past two centuries, disturbance from land management practices including land clearing and grazing, and changes to fire and flood regimes, have triggered substantial dense regrowth of woody vegetation in some areas. Although such 'recruitment' events are a natural response to disturbance, dense regrowth over large areas can have negative impacts on vegetation structure and habitat for wildlife (Kyle and Duncan 2012; Jones et al. 2015). For example, dense woody regrowth can reduce the density and diversity of ground cover and understorey vegetation (Hunter 2011; Jones et al. 2015). It can also inhibit the growth of trees, which can delay the development of tree hollows – essential habitat for a wide variety of fauna (Horner et al. 2010). At the site scale, large areas of dense woody regrowth can simply reduce the variety of habitats available to wildlife.

While areas of dense regrowth will naturally thin over time, the timeframe can be very long (decades or centuries). Ecological thinning aims to speed up natural stand development processes to restore greater structural diversity of habitat types in the landscape (Dwyer et al. 2010). Ecological thinning may provide additional benefits. For example, felled timber that remains on the ground has ecological value including stabilising soils, protecting ground cover germination and providing habitat for wildlife (Tongway and Ludwig 1996) (See Figure 1).

Research on the use of ecological thinning

In Australia, the causes of dense regrowth have only been investigated in a few vegetation communities, with significant attention given to White Cypress regrowth and River Redgums west of the ranges. In some Australian temperate forests, reduced fire frequency is thought to be the primary 'disturbance' that has resulted in the chronic decline of eucalypts and dense regrowth of some understorey tree species such as *Allocasuarina littoralis* (Lunt 1998, Close et al. 2009).

Thinning as a management tool has long been used in forest management worldwide to improve the growth rate of trees for timber harvesting (Ashton and Kelty 2018). The science behind *ecological* thinning attempts to understand the historical state or a desirable ecosystem structure, and to use reference tree densities as targets for thinning protocols. For example, thinning may aim to restore characteristics of pre-1750 vegetation, considered to have a large range of tree sizes and densities, even within the same vegetation communities (Gibbons et al. 2010).

A number of ecosystem benefits resulting from ecological thinning have been documented. As clearly established by the forestry industry, thinning speeds the growth of retained trees. This can result in the earlier formation of tree hollows and improve habitat for fauna (Horner et al. 2010). In some ecosystems, the diversity of woody species and grass cover has been shown to increase after thinning, as has the diversity of understorey vegetation (Dwyer et al. 2010; Jones et al. 2015).

The response of native flora and fauna to thinning depends on the species, with some species showing a preference for dense stands. Thinning has improved habitat for a range of birds, bats, reptiles, invertebrates and mammals (Gonsalves et al. 2018a). Considering different species have different habitat preferences, thinning activities should aim to create a mosaic or patchwork of stands of different densities, that will benefit a greater diversity of species.

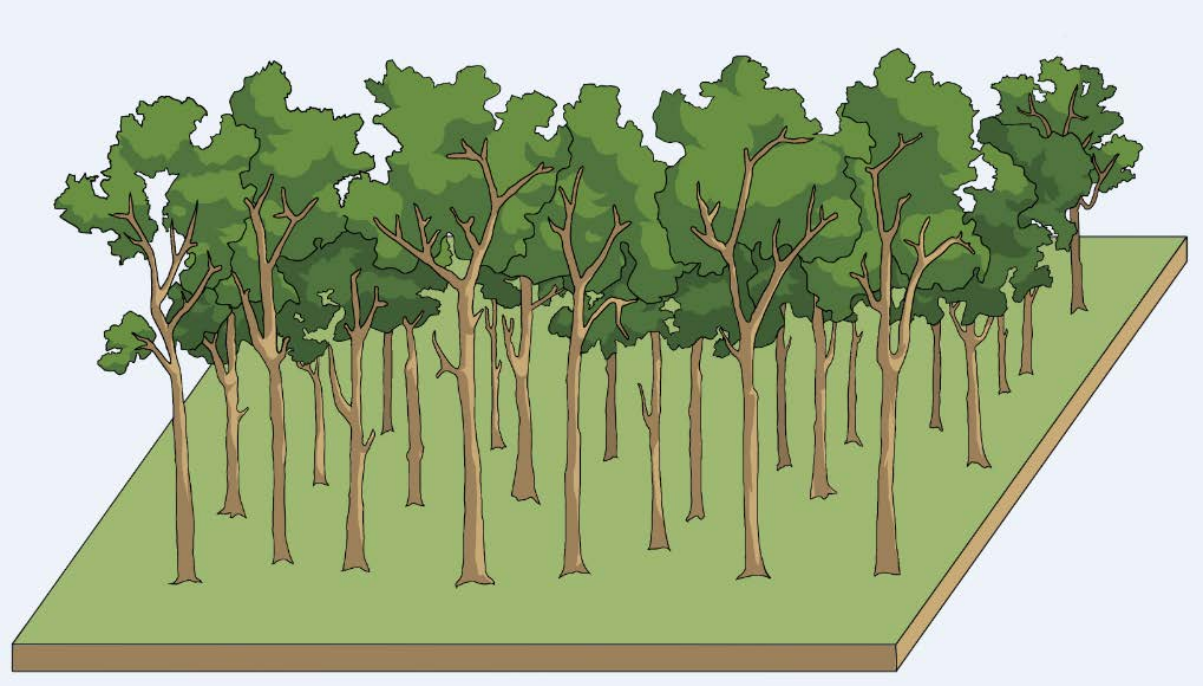
Sites that have high exotic plant cover prior to thinning (or development of the dense stand) are likely to see considerable growth of exotics after thinning due to the higher proportion of weed species in the seedbank. Significant exotic vegetation invasion could negate the value of thinning (Jones et al. 2015).

The relationship between erosion and dense re-growth is likely to be one of association, not cause (Eldridge, Wilson and Oliver 2003). Although dense stands of regrowth can lead to reduced ground storey vegetation, this reduction is usually compensated for by increases in other forms of ground cover, particularly twigs and litter from the trees, and living soil crusts. Felled timber retained on site can lessen erosion by intercepting runoff, soil and organic material, which can provide sites for plant establishment (Ludwig 1997). However, thinning solely for erosion control purposes currently lacks supporting evidence and is unlikely to be supported by the BCT.

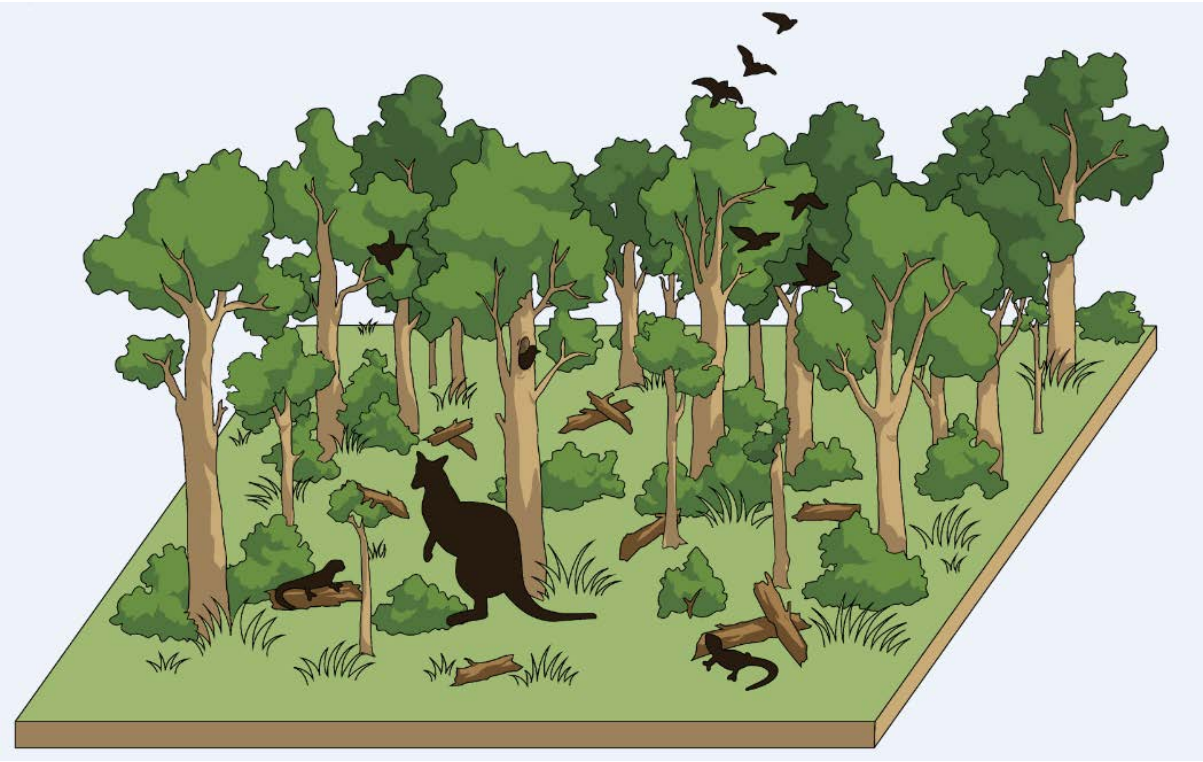
The use of thinning exclusively for ecological benefits is a relatively new area of study and there are still many areas of uncertainty. The results of thinning trials are often presented after short timeframes, while some ecological processes such as tree hollow formation can take more than 50 - 100 years, and the development of open woodlands even longer. These areas of uncertainty and the scientific findings presented above, are to be taken into consideration in determining if ecological thinning is an appropriate management action for your land. If it is determined that ecological thinning is appropriate for your site, monitoring the outcomes and applying adaptive management where required, will be essential to ensure positive outcomes for biodiversity.

Figure 1 Illustration of the desired conservation outcomes of ecological thinning. Top: Dense regrowth of a single tree species has inhibited the development and diversity of ground cover and understorey vegetation, and diversity of habitat for wildlife is minimal. Bottom: 20-80 years post ecological thinning – ground cover and understorey vegetation diversity has increased, felled timber and new vegetation types increase habitat diversity, and the maturation of retained trees has led to the development of tree hollows and additional habitat for wildlife.

Before ecological thinning



After ecological thinning



Is ecological thinning appropriate for your conservation area?

The decision tree in Figure 4 can be used to determine if ecological thinning may be suitable as a management action for the conservation area. This will primarily be based on the following factors at the site:

- The conservation objective
- Vegetation type and condition
- Size of management zones or paddocks
- Presence and management of threats[1].

BCT staff or an accredited assessor can help you apply the decision tree in Figure 4 (e.g. assist identifying vegetation condition, factors driving dense regrowth of vegetation, and assess the appropriateness of ecological thinning as a management approach). Table 1 lists the vegetation formations where ecological thinning will not be supported, and those formations for which ecological thinning may be considered suitable, in accordance with these guidelines.

Figure 2 Dense regrowth of Black Box woodland near Warren, NSW (Source: Kevin Chaplin)

[1] Grazing pressure from feral herbivores (particularly goats and rabbits) as well as domestic and native herbivores, suppression of fire (both wildfire and management burning), change in hydrology, climate change, etc.

Figure 3 Dense regrowth of White Cypress near Barooga, NSW (Source: Peter Ewin)

FIGURE 1

Flow chart to guide appropriate management options for ecological thinning in BCT agreement areas

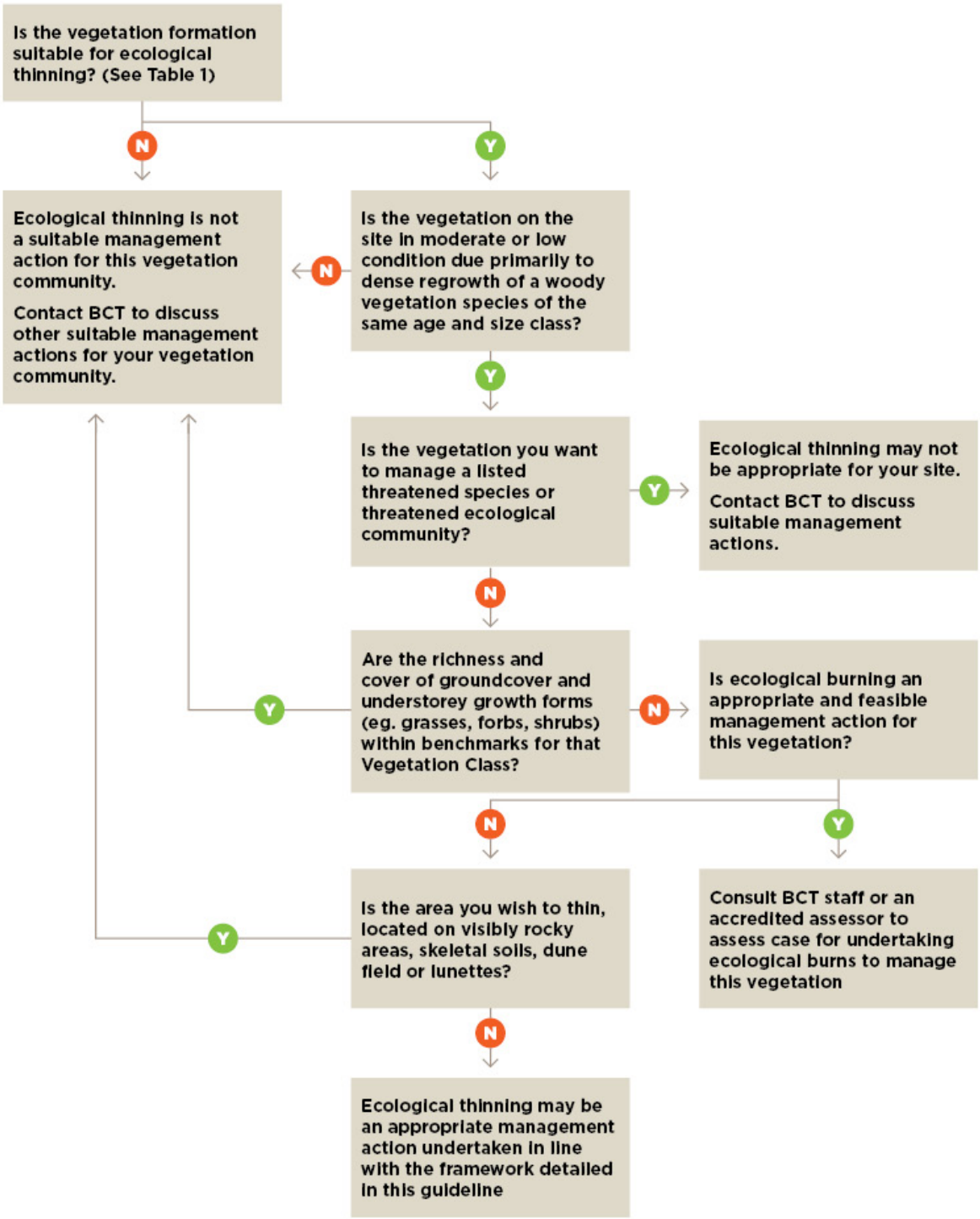


Figure 4 Decision tree to guide appropriate management options for ecological thinning in BCT agreement areas

Table 1 Vegetation formations where thinning may be a suitable management action (in accordance with these guidelines) or unsuitable (adapted from Landholder Guide: Guidelines for applying the Thinning of Native Vegetation Ministerial Order (thinning self-assessment), OEH 2015)

Vegetation Formation[1]	Coastal thinning zone[2]	Remaining areas of NSW
Arid Shrubland (Acacia sub-formation)	N/A	✓
Dry Sclerophyll Forests	✓	✓
Forested Wetlands	✗	✓
Grassy Woodlands	✓	✓
Semi-arid Woodlands	✓	✓
Wet Sclerophyll Forests	Thinning unsuitable	
Alpine Complex	Thinning unsuitable	
Arid Shrublands (Chenopod sub-formation)	Thinning unsuitable	
Freshwater Wetlands	Thinning unsuitable	
Grasslands	Thinning unsuitable	
Heathlands	Thinning unsuitable	
Rainforest	Thinning unsuitable	
Saline Wetlands	Thinning unsuitable	

[1] A map of the Keith Vegetation formation can be found on the Seed Portal by searching for "Keith formation version 3' www.seed.nsw.gov.au https://datasets.seed.nsw.gov.au/dataset/vegetation-classes-of-nsw-version-3-03-200m-raster-david-a-keith-and-christopher-c-simpc0917

[2] Coastal thinning zone applies to the following local government areas: Ballina, Bega Valley, Bellingen, Blue Mountains, Byron, Central Coast, Cessnock, Clarence Valley, Coffs Harbour, Dungog, Eurobodalla, Kempsey, Kiama, Kyogle, Lake Macquarie, Lismore, Mid-Coast, Nambucca, Port Macquarie–Hastings, Port Stephens, Richmond Valley, Shellharbour, Shoalhaven, Tweed, Wingecarribee, Wollondilly, Wollongong. For more information see *Guidelines for applying the Thinning of Native Vegetation Ministerial Order (thinning self assessible code)* (OEH 2015).

Principles for ecological thinning

To ensure ecological thinning actions are effective in achieving biodiversity conservation goals, the following principles for ecological thinning should be followed:

1. Ecological thinning will only be supported on in-perpetuity agreements for which timeframes to effectively monitor outcomes, provide follow up management and apply adaptive management, are long enough to achieve the desired ecological outcomes.

2. Limit the application of ecological thinning to supporting either: the enhancement of habitat for target threatened species, and/or supporting the improvement in condition of vegetation, where the richness and cover of plant growth forms associated with the understorey vegetation strata (e.g. shrubs, grasses and forbs), are below benchmark values.

3. Ecological thinning within and across management zones is designed to achieve a patchy mosaic of stand structures with different tree densities and ages across the site. A proportion of the conservation area should remain un-thinned to retain some high-density patches.

4. Maintain the connectivity of wooded habitat. A single small area of woody vegetation less than 2 ha in size that is isolated by more than 100m from other woody vegetation is generally not suitable for thinning.

5. Retain all large and significant habitat trees. Habitat trees have any of the following characteristics:
    - at or above the large tree threshold for the vegetation class at the site
    - the largest age-class trees in the patch
    - standing dead trees, or dying trees
    - containing tree hollows potentially used by fauna
    - signs of current or recent occupation by fauna.

6. Retain any Aboriginal culturally modified tree i.e. any tree that has been scarred, carved or modified by an Aboriginal person by traditional methods. Ensure other Aboriginal sites such as oven mounds, middens and burials are not negatively impacted.

7. Thinning should not automatically remove all trees below a tree stem size class. A representation of young and maturing trees should be retained.

8. Restore the relative proportions of tree species (guided by tree richness benchmarks and the relevant PCT profile) by only thinning those species displaying dense regrowth.

9. Thin to a density above the reference tree stem size class densities for the target vegetation, to allow for natural die-off.

10. Ensure little or no disturbance of the ground cover and native understorey plants. Stumps should be left in the ground.

11. Retain all felled timber on-site to provide ground habitat, except where removal is discussed with BCT. For example, removal may be allowed where the volume of felled timber would pose a significant impediment to understorey regeneration or where it would pose an unacceptable fire risk to nearby property assets.

12. Manage any negative impacts of ecological thinning so that effects on ecological integrity and biodiversity are negligible or minimal.

BCT ecological thinning framework

The framework in Figure 5 can be applied for agreements where ecological thinning is identified as a potentially suitable management action. For existing agreements this action must be permitted by the terms of the agreement. This framework guides the development of management actions that aim to support biodiversity conservation and the overarching conservation objectives of the site. It identifies six stages to help develop ecological thinning management actions specific to your property. More detailed information about each stage is provided below. BCT staff or an accredited assessor can help you apply this framework.

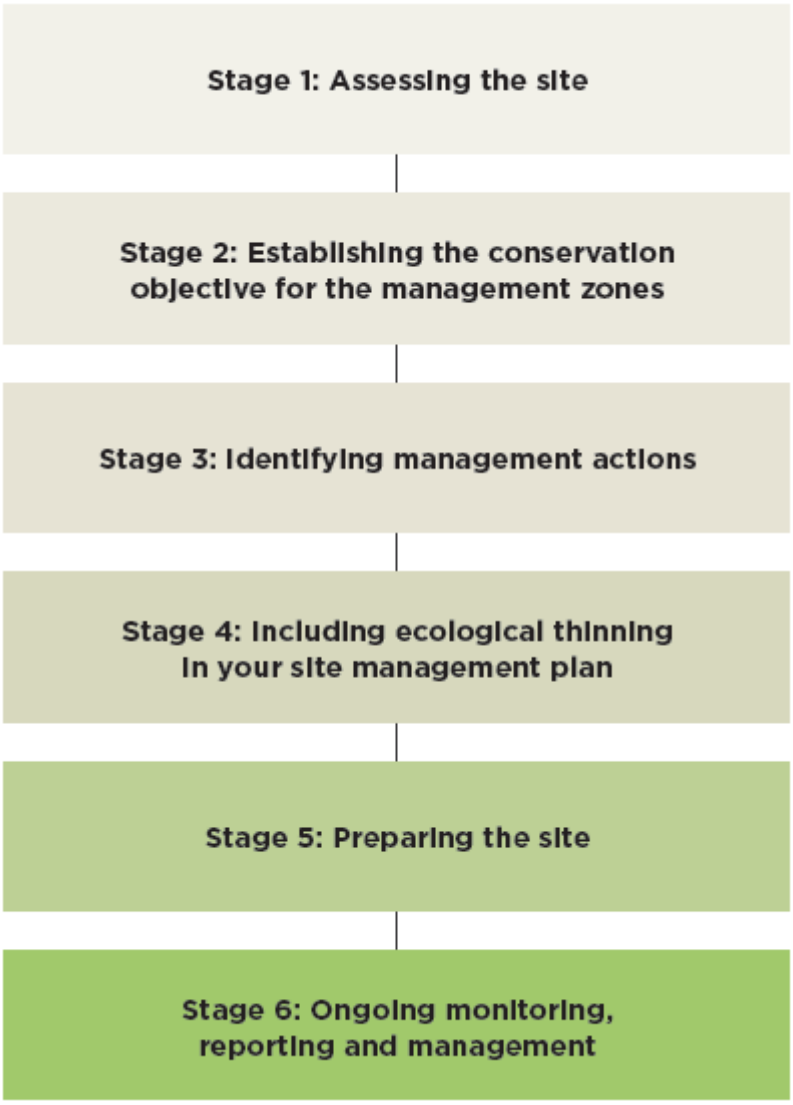


Figure 5 BCT ecological thinning framework

Stage 1 – Assessing the site

As part of your agreement, BCT staff or contractors (conservation agreements), or accredited assessors (biodiversity stewardship agreements) will assess the site to determine the vegetation types present, their current condition, and the natural resilience of the vegetation. Ideally, information on the distribution of dense regrowth across the site will also be collected. This information is used to help determine conservation objectives for identified management zones, inform whether ecological thinning is likely to support the conservation objective, and identify what other complementary management actions may be required.

Vegetation condition and resilience are influenced by the site's management history, for example, fertiliser use, past vegetation clearing, addition of pasture species, grazing intensity and extent of weeds. The *resilience* of a vegetation community refers to its ability to recover from disturbance or threats, and is influenced by many factors. A high diversity of plant growth forms, and high native plant species richness and cover, for example, can contribute to the resilience of a vegetation community by replenishing the native seedbank for regeneration. Major threats existing on the site will be identified. These include any threats to biodiversity that may fluctuate over time, such as the presence of invasive plants. Where possible, these threats will be addressed before undertaking ecological thinning. This is to maximise the effectiveness of ecological thinning if it is appropriate for the site.

If the site is in poor condition, with low native species diversity and/or specific elements of the plant community type absent, then any proposed ecological thinning may need to occur together with assisted regeneration or revegetation. This will support the regeneration of ground cover or understorey growth forms (e.g. grass, forbs, shrubs) toward benchmark levels for cover and richness. If this is the case, these guidelines should be applied in conjunction with the BCT *Guidelines for Assisted Regeneration and Revegetation*.

Stage 2 – Establishing your conservation objective for the management zones

The goal for any conservation area is to maintain or enhance the biodiversity values present. Achieving this goal will typically include setting objectives to improve native vegetation towards a benchmark or reference condition. Your specific conservation objectives will depend on the context of your site. For example, your objective may be to achieve a patchy mosaic of different density stands across the management zones in your site to support a diverse array of fauna. This may involve maintaining some zones as as high density, and thinning others, depending on the distribution of high density stands on the site (see example in Figure 6). Another objective may be to provide habitat for specific target threatened species by increasing the amount of fallen timber on the site or facilitating the development of large, hollow bearing trees.

To determine your conservation objective, it is important to identify the impact that the dense regrowth of vegetation is having on the vegetation and fauna of the site. For example, dense regrowth of a particular tree species may be impacting on the diversity and cover of grass, herb and shrubs, or inhibiting the growth of desired habitat trees. Information such as the benchmark conditions for the vegetation on your site, or the habitat requirements for a threatened species, can help you identify goals and refine your conservation objective.

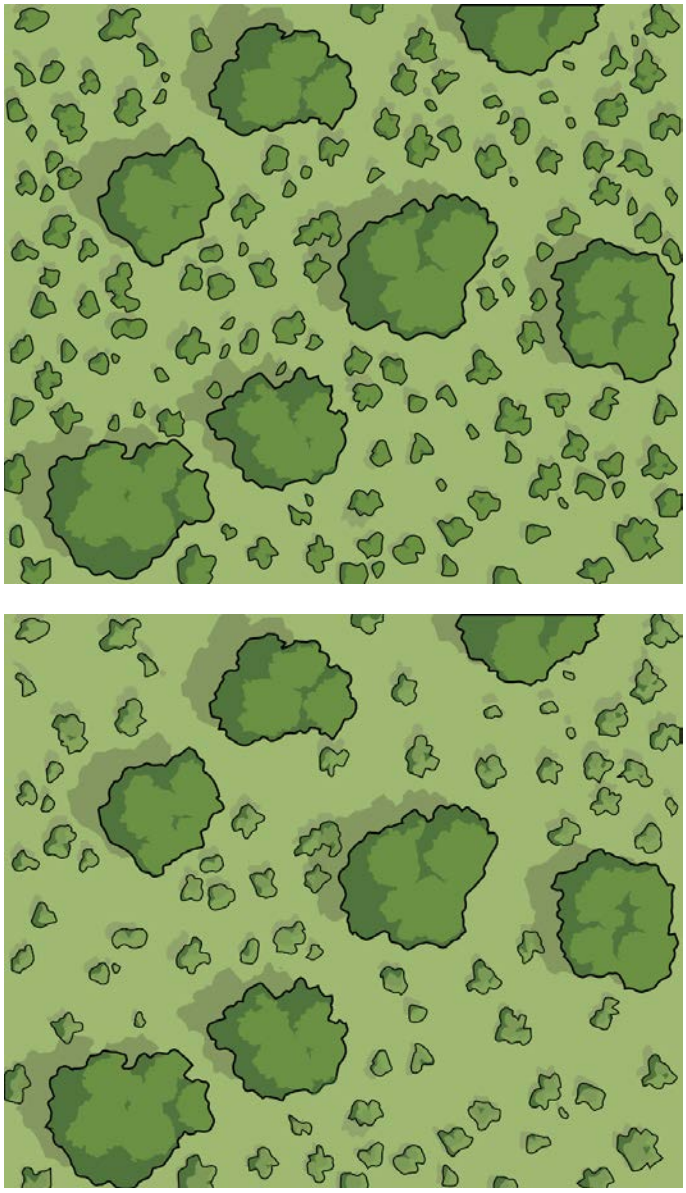


Figure 6 Graphical representation of one approach to ecological thinning. Top: aerial view of an unthinned stand of trees. Bottom: All large habitat trees are retained and selected trees from the dense regrowth are removed to achieve a range of different tree densities across the site.

Stage 3 – Identifying your management actions

In order to determine what management actions are most appropriate for the site, the following six factors will need to be considered:

1. Conservation objectives
2. Vegetation condition
3. Degree of resilience
4. Stem density and spacing appropriate for your vegetation community
5. Threats and site conditions
6. Budget.

Identifying management actions for relevant management zones should be based on an understanding of the current condition of your vegetation, the ability to manage current threats and the costs and resources needed to achieve the intended conservation objectives.

If ecological thinning is identified as an appropriate management action, BCT staff or an accredited assessor will identify the target stem density for the species proposed to be thinned. The target density will be informed by stem size class densities at a reference site, or available tree stem size class data for a comparable vegetation type. The BCT recommends that the maximum DBH for trees allowed to be thinned would be 25 cm for Eucalypt species and 15 cm for other tree species. However, in some cases (such as in arid locations), the maximum DBH may be smaller. This will be determined on a case by case basis by an accredited assessor or the BCT, and appropriate justification provided.

BCT staff or an accredited assessor will also help you determine appropriate spacing for thinning activities and retained trees. Depending on the conservation objective, thinning may be carried out to a set spacing, where retained trees are spread evenly over the management zone. Another approach may be to identify specific trees to be retained and apply thinning to dense regrowth immediately surrounding these. It may be desirable to vary the intensity of thinning within or across management zones to maximise landscape variability and support a diversity of habitats across the site.

Additional complementary management actions may be required for ecological thinning to meet the conservation objectives. This will be influenced by the condition and resilience of the vegetation at the site, as illustrated in Table 2. The best strategy for a site may be to combine multiple approaches and management actions. For example, if the site is more degraded and less resilient, ecological thinning may promote the establishment of weeds instead of desired native species, unless other management actions such as assisted regeneration and/or revegetation[2] are undertaken.

Always consider if it is worth investing the resources to successfully undertake ecological thinning, including the associated management actions needed to successfully achieve the conservation objectives. The most cost effective, less labour-intensive methods are preferable, provided they will enable you to meet your short- and long-term objectives. Site condition and budget will help determine the most appropriate thinning method for the site. Ecological thinning methods are detailed in the following section.

[2] Refer to the BCT Guidelines for Assisted Regeneration and Revegetation.

Table 2 Level of degradation/resilience and appropriate management actions

Level of degradation	Level of resilience	Example	Ecological thinning and restoration approach	Actions
LOW	HIGH	- Near natural or little disturbance - High density of tree species X - Old remnant trees present - Numerous young native saplings - High shrub, grass and forb species diversity in relation to benchmarks - Native grasses and leaf litter present	Ecological thinning and natural regeneration	- Manage threats - Undertake thinning - Identify regeneration performance thresholds that will trigger assisted regeneration
MODERATE	MODERATE	- Modified site, subject to prolonged or repeated disturbance - Few remnant large trees within the area of dense regrowth - Understorey growth forms (e.g. shrubs) missing or lacking in diversity - High proportion of bare ground - Weeds present	Ecological thinning followed by: - Weed control - Assisted regeneration - Potential supplementary planting	- Remove or manage cause of disturbance/degradation - Undertake thinning - Identify assisted regeneration management actions - Supplementary planting of understorey or ground cover plants e.g. shrubs, grasses, herbs.
HIGH	LOW	- Low species diversity - Few, if any, living large trees within the area of dense regrowth - High presence of weeds and pasture grasses - Soil erosion	Ecological thinning followed by: - Weed control - Assisted regeneration for some species - Revegetation	- Remove or manage cause of disturbance/degradation - Undertake thinning - Identify regeneration performance thresholds that will trigger assisted regeneration or revegetation - Reintroduce understorey or ground cover plants e.g. shrubs, grasses, herbs.

Methods to undertake ecological thinning

The technique proposed for ecological thinning is also known as ‘selective thinning’. This involves the removal of individual trees to achieve the desired density of trees over the management zone. BCT staff, an accredited assessor, or an appropriately experienced/qualified person should undertake the work to ensure that the trees to be thinned are correctly identified and spacing is correctly considered. Marking trees for retention or thinning in stages, are two approaches that can be used to ensure the desired densities are achieved.

An appropriate thinning method must be identified in consultation with BCT and detailed in your management plan. Non-selective mechanical means of thinning such as chaining, or blade ploughing cannot be used, the exception being mowing or slashing which targets seedlings or juvenile trees less than 1.5 m. All techniques must minimise ground disturbance as much as possible. The technique suitable for the site will depend on the species, size and number of individuals proposed to be thinned, terrain and access. Table 3 details different approaches to manual thinning methods, including when they can be used and the associated pros and cons.

Table 3 Summary of selective thinning techniques including pros and cons of different methods

Technique	Consider this technique when	Pros	Cons
Chainsaw Felling with a chainsaw. Direct application of herbicide to cut stump soon after cutting can prevent reshooting in species that coppice.	Larger trees require felling. Where some timber on the ground will be beneficial for erosion. One of the preferred methods.	Low disturbance of ground cover (e.g. grasses and forbs). Targets specific individual trees.	Labour intensive. Difficult or costly job with potential work, health and safety risks. Fire behaviour can be influenced by coarse woody debris.
Stem injection Holes drilled into the bark or 'frilled' with an axe and herbicide applied. Specialised stem injectors or herbicide axes can improve efficiency.	Where dead stems can remain standing.	Retains standing trees for habitat. Herbicides can be limited in their action on some species.	Labour intensive. Difficult to use on stems less than 5cm diameter.
Brushcutter	For young plants with a diameter <7 cm or <1.5 m tall.	Can accurately target specific plants.	Labour intensive. Fire behaviour can be influenced by coarse woody debris. Some regrowth can be expected and require follow up cutting.
Slashing and mowing	Suitable for young seedlings only especially after a large emergence event following rainfall or a disturbance event. Wait until after the first summer following emergence as dry summers can kill most seedlings.	Easily accessible and usable method.	Hard to target juvenile and seedling without affecting non-target species. Cannot be used when ground species are flowering and setting seed. Cannot be used where there is established understorey.

			Cannot be used where there are significant volumes of coarse woody debris, or rough or rocky terrain.
Chipping Thinning seedlings with a mattock or similar lighter tool	Suitable for seedlings <1.5 m	Environmentally benign, will not harm nearby large trees. No large equipment needed. Once desired structure of larger trees is achieved, follow up maintenance is minimal. Can be highly selective.	Small-scale activity, requiring physical work.
Mulching Thinning immature trees with a rubber tracked forestry mulcher	Thinning seedlings, shrubs or juvenile trees (e.g. <1.5m in height) over large areas.	Efficient over large areas. Minimal disturbance to soil. Thinning area may benefit from mulch produced in the process.	Not as selective as individual stem selection methods e.g. chainsaw or brushcutter. Potential for mulch to smother ground cover.

Stage 4 – Include ecological thinning as part of your site management plan

It is important to plan ecological thinning within the context of other related management actions and set realistic targets and timeframes to reach your conservation objective.

The following steps outline what needs to be included in your management plan. BCT staff can assist you develop your management plan and identify the most suitable management actions for the site.

1. Identify and map the location and extent of areas proposed for ecological thinning as specific management zones, or identify areas to be thinned within existing management zones. BCT staff or an accredited assessor will create a map of the site, identifying the different vegetation types and their condition, including any sensitive areas and watercourses. The map will also identify which, if any, areas of vegetation may have poor resilience (e.g. reduced native vegetation cover and diversity, or high weed cover), that will require other management actions in combination with ecological thinning.

2. Set out clear objectives, with timeframes, for each management zone. A clear objective is a fundamental part of the planning process and will allow the future success of the project to be measured. Identify timeframes that are realistic given the site condition and available resources. Set long-term objectives first and use short-term targets as steps to help reach them.

3. Detail the requirements for management for both ecological thinning and any associated management actions such as weed management, assisted regeneration or revegetation. The management plan should include:
    - site preparation for each management zone including weed management, stock exclusion or fencing
    - ongoing maintenance required
    - measures of success and monitoring requirements (see Stage 6 for more details)
    - contingencies in the event of failure.

4. Establish a schedule of events. Plan the timing of ecological thinning per zone, as this may be staged by management zone or season. Consider timing relative to other management actions such as weed management, fence installation or time critical management actions such as revegetation.

5. The management plan should also provide detailed prescriptions, including:
    - density targets per tree stem size class for the species to be thinned, based on a reference site or appropriate data
    - the maximum stem size allowed to be thinned (refer to Stage 3).

Stage 5 – Preparing the site

A well-prepared site will enable you to better manage vegetation both during and after ecological thinning. The steps identified below will vary depending on local conditions and the thinning method used.

1. Establish or maintain fences to exclude stock. Ideally, sites proposed to be thinned should be fenced before thinning is undertaken. Management of total grazing pressure (i.e. feral, native and domestic animals) is essential for the long-term success of your conservation area's objectives. See BCT Managing Overabundant Kangaroo Guidelines for more information.

2. Where possible, undertake weed control well in advance of thinning. Plants compete for space, light, water and nutrients, so once an area has been thinned, weeds can take advantage of this increase in light and nutrients. Undertaking weed management before ecological thinning will give your desired plants the advantage once thinning has been undertaken. Weed control[3] may involve boom spraying, spot spraying, scalping, mulching, use of weed mats and under certain circumstances intensive grazing[4]. Consider whether the time of year is important.

Stage 6 - Ongoing monitoring, reporting and management

Ongoing monitoring and reporting are required to assess the extent to which conservation outcomes are being met. This information can guide adaptive management to address any observed problems or shortcomings in the management activities applied. Monitoring and reporting of all conservation agreements will be undertaken in accordance with the BCT's Ecological Monitoring Module.

Record keeping for ecological thinning activities

For funded conservation agreements and biodiversity stewardship agreements you will be required to record and report on:

- when thinning occurred
- the thinning method applied
- DBH range and the proportion of density reduction achieved through thinning
- the species thinned
- stem density of thinned species before and after thinning
- pre-thinning ground preparation (if required), e.g. weed control methods
- climatic conditions leading up to and after thinning.

Monitoring and reporting

The only way to identify whether your ecological thinning action is working as expected, or whether it needs to be modified, is by monitoring your progress. As part of your agreement, you, in collaboration with BCT staff or an accredited assessor, will be required to monitor and report on progress. This will comprise both *performance measures* – i.e. progress on the implementation of management actions (e.g. number, species and size of stems removed, area of weeds sprayed), to be reported on an annual basis, and *ecological outcomes* – i.e. state and change in ecological condition (e.g. cover, diversity and abundance of native species), to be reported over a longer timeframe (e.g. 5 yearly).It is important to set a quantifiable target for each management zone (adhering to the SMART principles;

[3] Any chemical use should be undertaken consistent with appropriate regulatory requirements and safety procedures and seek minimal impact on existing native vegetation at the site.
[4] Consult with BCT staff and refer to BCT *Livestock Grazing Guidelines for Private Land Conservation.*

specific, measurable, achievable, realistic, timebound), for example, reduction of ‘X%’ of the extent of ‘Y’ species in the management zone by ‘Z’ year.

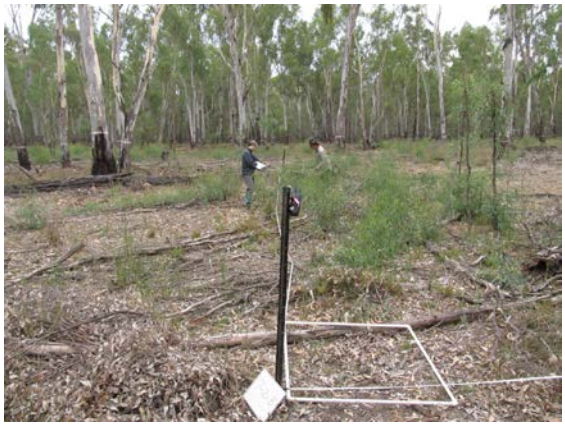
After thinning has been undertaken, there may be some level of maintenance required to achieve the objectives of the site. Monitor and record the response of the vegetation and any maintenance undertaken. For example, there may be some regrowth of thinned species, other native species may start regenerating or weed species may establish in the thinned area. Keep a record of the date and type of any maintenance such as weeding, feral species control, or watering of seedlings, and record any plantings if revegetation is part of the management actions for the management zone. Additional, more intensive ecological monitoring will be undertaken by either a qualified contractor or BCT staff.

Photos can be a useful way to illustrate changes that occur with ecological thinning efforts (see example in Figure 7). BCT staff or an accredited assessor will set up permanent photo points for you to take photos before thinning takes place, just after thinning has been undertaken, and at regular intervals after thinning has occurred (e.g. every 3 months). These photos are to be submitted as part of the annual report.

Note: If you have a funded conservation agreement or a biodiversity stewardship agreement, your agreement will specify the minimal monitoring and reporting requirements you are contractually required to undertake.

2015 (before ecological thinning)

2017



2018

2019

Figure 7 Photos taken pre- and post-ecological thinning from a fixed photo point (Source: Ecological thinning trial in river red gum forests - Department of Planning, Industry and Environment)

Ongoing management and continual improvement

The results of monitoring can be used as a basis for continual improvement. The site can be monitored for results of ecological thinning and the management plan adapted accordingly if the response isn't meeting the conservation objectives. For example, in some cases a second application of thinning may be required to address regrowth of the thinned species. Adaptive management options should be discussed with BCT staff.

Minimising negative impacts of ecological thinning

The following section describes ways in which negative impacts on biodiversity can be minimised during ecological thinning.

Retention of Aboriginal Cultural Heritage Values

Private land within NSW contains various forms of significant sites and features within the landscape. Aboriginal culture is connected to Country, including waterways, mountains, wetlands, floodplains, hills, sandhills, rock outcrops and the biodiversity within these landscape features. Many of these features are known to have cultural value and culturally significant sites. These elements of the landscape are associated with Dreaming stories and cultural learning.

Private land conservation agreements should minimise the risk of management actions negatively impacting Aboriginal places and objects. The BCT will conduct an Aboriginal Heritage Information Management System (AHIMS) search as part of due diligence in preparation of the agreement. This is to identify known Aboriginal sites within the agreement area. Ecological thinning undertaken in accordance with these guidelines would typically be considered to be low risk, due to low disturbance of the site.

If you are unsure of what an Aboriginal site is, please refer to the Aboriginal Heritage Information Management System (AHIMS, https://www.heritage.nsw.gov.au/search-for-heritage/aboriginal-heritage-information-management-system/).

Retention of mature trees and range of maturing trees

Large mature trees must be retained as they form the structural matrix for forests and woodlands, providing the major food and habitat resources for fauna, and seed for future regeneration. Retaining large trees will reduce the loss of habitat for tree-dwelling fauna and help to reduce the regeneration gap of trees required to replace the large old hollow trees that are in decline or have already been removed from the landscape.

The guideline explicitly states the retention of all trees greater than 25 cm DBH for Eucalypt species and 15 cm DBH for other tree species (i.e. no thinning of trees above that size). However, DBH does not necessarily reflect a specific age of vegetation. Age and size differences may be due to non-ecological site factors and some sites may contain significant numbers of narrow but mature trees. The retained stems must include the largest stems present on each hectare prior to thinning.

Exotic weeds

Thinning can provide opportunities for the establishment of exotic vegetation which in many cases can respond more favourably to the thinning than the native species. Thinning in areas of high exotic plant density is not recommended. Where thinning is identified as a suitable management action,

control of exotic species must be included as a management action for relevant management zones and timed appropriately.

Disturbance of ground cover

There should be little or no disturbance of the ground cover. Stumps should be left in the ground. Mechanised, non-selective clearing, such as chaining and bulldozing, which push over trees is not supported. Targeted manual thinning is the preferred option, as outlined in Table 3. Retained felled timber on the ground has ecological value including stabilizing soils, protecting germination within ground cover and providing habitat. However, retained timber can also increase fire fuel loads and needs to be considered in relation to bush fire risk planning.

Site specific variation

Site specific variation needs to be incorporated into thinning protocols. For example, there may be different benchmarks for parts of a vegetation community within high value conservation areas or riparian zones. Some areas of the landscape may be able to support higher densities (for example as a result of deeper soils, or greater water retention). Alternatively, higher thinning rates may be appropriate in some management zones. Thinning is not appropriate for some land types including most riparian zones, skeletal soils, dune fields or lunettes. Habitat connectivity should also be considered for specific species. Sites containing a single small area of woody vegetation less than 2 ha in size that is isolated by more than 100 m from other woody vegetation is not suitable for thinning.

Literature cited and further reading

Below is a list of the relevant literature cited in these guidelines and additional resources to provide you with further information on ecological thinning and how it relates to conservation objectives. The NSW BCT does not necessarily endorse all opinions or ideas contained within these resources.

Ashton, M.S., Kelty, M. J. (2018) The practice of silviculture: applied forest ecology. Wiley, Hoboken, p 776.

Close D.C., Davidson N.J., Johnson D.W., Abrams, M.D>, Hart, S.C., Lunt, I.D., Archibald, R.D., Horton, B and Adams, M.A. (2009) Premature decline of eucalyptus and altered ecosystem processes in the absence of fire in some Australian forests. *The Botanical Review 75*, 191–193.

Cohn, J. S., Lunt, I. D., Bradstock, R. A., & Koen, T. (2012). Interactions between dense Callitris regeneration and Eucalyptus and Callitris canopy trees in semiarid woodlands. *Australian Journal of Botany*, *60*(6), 549-558.

NSW Department of Planning, Industry and Environment (DPIE). (2020) Biodiversity Assessment Method. Department of Planning, Industry and Environment, Sydney.

Dwyer, J. M., Fensham, R., and Buckley, Y. M. (2010). Restoration thinning accelerates structural development and carbon sequestration in an endangered Australian ecosystem: restoration thinning in natural regrowth. Journal of Applied Ecology, 47, 681–691. doi:10.1111/ J.1365-2664.2010.01775.X

Eldridge, D. J., Wilson, B. R., & Oliver, I. (2003). Regrowth and soil erosion in the semi-arid woodlands of New South Wales. *NSW Department of Land and Water Conservation, Sydney*.

Fensham, R. J. (2008). A protocol for assessing applications to selectively clear vegetation in Australia. *Land Use Policy*, *25*(2), 249-258.

Gibbons, P., Briggs, S. V., Murphy, D. Y., Lindenmayer, D. B., McElhinny, C., & Brookhouse, M. (2010). Benchmark stem densities for forests and woodlands in south-eastern Australia under conditions of relatively little modification by humans since European settlement. *Forest Ecology and Management*, *260*(12), 2125-2133.

Gonsalves, L., Law, B., Brassil, T., Waters, C., Toole, I., & Tap, P. (2018a). Ecological outcomes for multiple taxa from silvicultural thinning of regrowth forest. *Forest ecology and management*, *425*, 177-188.

Gonsalves, L., Law, B., & Blakey, R. (2018b). Experimental evaluation of the initial effects of large-scale thinning on structure and biodiversity of river red gum (*Eucalyptus camaldulensis*) forests. *Wildlife Research*, *45*(5), 397-410.

Horner, G. J., Baker, P. J., Nally, R. M., Cunningham, S. C., Thomson, J. R. and Hamilton F. (2010) Forest structure, habitat and carbon benefits from thinning floodplain forests: managing early stand density makes a difference. *Forest Ecology and Management, 259*:286–293.

Hunter, J. T. (2011). A broad brush-stroke test of an assumption: does increasing Callitris cover reduce native species richness (species density)? *Cunninghamia, 12*(2), 115-118.

Jones, C. S., Duncan, D. H., Rumpff, L., Thomas, F. M., Morris, W. K., & Vesk, P. A. (2015). Empirically validating a dense woody regrowth 'problem' and thinning 'solution' for understory vegetation. *Forest Ecology and Management*, *340*, 153-162.

Kutt, A. S. (1994). Arboreal marsupials and nocturnal birds in thinned regrowth, unthinned regrowth and old lowland forest, East Gippsland, Victoria. *Australian Forestry*, *57*(3), 123-130.

Kyle G. & Duncan D. H. (2012) Arresting the rate of land clearing: Change in woody native vegetation cover in a changing agricultural landscape. *Landscape and Urban Planning, 106*, 167-73.

Ludwig, J., Tongway, D., Freudenberger, D. Noble, J. (1997). *Landscape Ecology: Function and Management*. CSIRO, Melbourne

Lunt, I. D. (1998) *Allocasuarina* (Casuarinaceae) invasion of an unburnt coastal woodland at Ocean Grove, Victoria: structural changes 1971–1996. *Australian Journal of Botany 46*, 649–656

Lunt, I. D., Jones, N., Spooner, P. G., & Petrow, M. (2006). Effects of European colonization on indigenous ecosystems: post-settlement changes in tree stand structures in Eucalyptus–Callitris woodlands in central New South Wales, Australia. *Journal of Biogeography*, *33*(6), 1102-1115.

New South Wales Government (2013). Native Vegetation Regulation 2013 Environmental Outcomes Assessment Methodology, NSW Office of Environment and Heritage.

NSW Office of Environment and Heritage (OEH). Ecological thinning trial in New South Wales and Victorian River Red Gum forests: Experimental design and monitoring plan, NSW Office of Environment and Heritage, 59 Goulburn Street, Sydney, NSW, 2000. https://www.environment.nsw.gov.au/resources/protectedareas/140083ecothinredgumapps.pdf

NSW Office of Environment and Heritage (OEH). River Red Gum Ecological Thinning Trial - Monitoring report 2019. National Parks and Wildlife Service. NSW Office of Environment and Heritage, 59 Goulburn Street, Sydney, NSW, 2000 https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/River-red-gums/river-red-gum-ecological-thinning-trial-monitoring-report-2019-190259.pdf

NSW Office of Environment and Heritage (OEH). (2015) Guidelines for applying the *Thinning of Native Vegetation* Ministerial Order (thinning self-assessable code). NSW Office of Environment and Heritage, 59 Goulburn Street, Sydney, NSW, 2000 https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Native-vegetation/guidelines-for-applying-the-thinning-of-native-vegetation-150008.pdf

Pike, D. A., Webb, J. K., & Shine, R. (2011). Chainsawing for conservation: ecologically informed tree removal for habitat management. *Ecological Management & Restoration*, *12*(2), 110-118.

Thompson, W. A., & Eldridge, D. J. (2005). Plant cover and composition in relation to density of *Callitris glaucophylla* (white cypress pine) along a rainfall gradient in eastern Australia. *Australian Journal of Botany*, *53*(6), 545-554.

Thompson, W. A., Eldridge, D. J., & Bonser, S. P. (2006). Structure of biological soil crust communities in *Callitris glaucophylla* woodlands of New South Wales, Australia. *Journal of Vegetation Science*, *17*(3), 271-280.

Tongway, D. J. & J. A. Ludwig. (1996). Rehabilitation of semi-arid landscapes in Australia. I. Restoring productive soil patches. *Restoration Ecology 4*:388 – 397.

Total Earth Care (TEC) 2010, Conservation assessment and resilience mapping Ecology Reserve, Macquarie University, unpublished report prepared for Macquarie University Office of Property.