PROJECT PHOENIX

BUSHFIRE IMPACTS

HOW MUCH SEED WILL I NEED?

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Australian Government

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Across all of our Project Phoenix activities and actions we pay respect to the Traditional Owners and Custodians of the lands and waters on which we work. We honour the resilience and continuing connection to country, culture and community of all Aboriginal and Torres Strait Islander people across Australia. We recognise the decisions we make today will impact the lives of generations to come.

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EXECUTIVE SUMMARY

- The Black Summer Fires of 2019–20 were unique in terms of the spatial extent of the fire scar and representation of different vegetation community types in fire affected areas. This led to questions about the role of native seed in bushfire recovery and the amount of native seed, seedlings and/or propagules that may be needed to support recovery.
- The Project Phoenix report *Bushfire impacts — A national model for assessing local landscape restoration priorities* (2021) involved the development of a science-based framework to make decisions regarding when and how to intervene to assist the recovery of fire affected vegetation communities. Central to this framework is understanding the inherent regenerative capacity of different vegetation communities and how this relates to species composition and traits. This trait information can then be combined with assessments of habitat condition, fire severity and landscape context to assess the need for intervention.
- This assessment can then be used to predict where seed might be needed for targeted reintroduction to ensure that:
  - natural regeneration is supported, and
  - limited seed resources are only used where required and/or appropriate.

  This involves a staged approach that minimises seed input through targeted seed use.
- Following on from Project Phoenix, *Bushfire impacts — A national model for assessing local landscape restoration priorities*, this project aims to present general seedling addition rates for different life form groups (trees, shrubs and herbaceous species) for different vegetation community types focusing on fire sensitive obligate seeders. To provide a range of potential inputs, we provide estimates for scenarios from reintroducing 10% of the fire sensitive species through to reintroducing all (100%) of the fire sensitive species.
- We provide these broad seedling addition rates for five example Threatened Ecological Communities (TEC) representing different vegetation types. Actual seed inputs can only be evaluated after on-ground site assessments, but the goal of these broad estimates is to compare different communities (with different degrees of fire sensitivity) and provide a general basis for the native seed sector to plan for potential seed needs for bushfire-affected areas.

1 INTRODUCTION

1.1 Bushfire recovery and native seed

1.1.1 The potential role of native seed in bushfire recovery

The Black Summer Fires of 2019–20 were unique in terms of the spatial extent of the fire scar, the representation of different vegetation community types in fire affected areas (e.g., rainforests and alpine vegetation) and impacts on flora and fauna communities in Australia.[1,2] Since this time, there has been considerable investment in bushfire recovery activities,[3] but given the wide-ranging impacts of these fires there are still gaps in our understanding of where management intervention may be required for Threatened Ecological Communities (TEC), how to prioritise management intervention within these communities and what the role of plant restoration is (via seed, seedling and/or propagule inputs) in this process.

There are three main uses of native plant seed in bushfire recovery:

1. As a response to the most recent fire event where seeds, seedlings and/or propagules may be required to assist the recovery of non-regenerating plant groups in fire affected areas. This may include key structural elements, dominant species and/or species of conservation concern.
2. Supplementing current populations or assisting the recovery of non-regenerating populations of plant species that are food sources and/or provide essential habitat for threatened fauna.
3. As a means of increasing the resilience of fire affected vegetation communities. More generally, this can be achieved by expanding the current spatial extent and/or creating new patches to increase connectivity across the landscape. Resilience to future fire events can be achieved by establishing buffers around existing patches and/or insurance populations elsewhere in the landscape.

In *Bushfire impacts — A national model for assessing local landscape restoration priorities* we presented a science-based framework that can be used to make decisions regarding when and how to intervene to assist the recovery of fire affected vegetation communities. Having decision-making tools can provide the basis for a management approach based on facilitating natural regeneration and one where limited resources — particularly seed and seedling inputs — can be strategically directed to specific situations and combined with other interventions to maximise ecological outcomes.

Essential to understanding the inherent regenerative capacity of different community types is information on species composition and plant functional traits. This information can then be used to assess how intervention can facilitate regeneration in the context of habitat condition.

We outline an approach that follows the recently revised SERA standards;[4] here, the degree of intervention scales along a degradation spectrum from Protection/Natural Regeneration and Facilitated regeneration through to interventions requiring seed and/or plant addition (Combined regeneration/reintroduction and Reconstruction) (see Figure 2.1-1). In this framework, we combine knowledge of plant traits and community composition with information on site variables that influence regenerative capacity to provide a means of assessing where seed input may be needed to assist the recovery of non-regenerating functional groups and species.

1.1.2 The importance of plant traits

One of the key variables in understanding the regenerative potential of a vegetation community is the fire response of the species within that community. Species can generally be classified into three broad categories of fire response:

1. **obligate seeders** (OS) that lack the ability to resprout and only regenerate from seed post-fire
2. **facultative seeders** (FS) that can regenerate via either resprouting or seed germination post-fire and
3. **resprouters** (RS) that rely solely on resprouting for post-fire regeneration.[5,6]

Generally, communities with a higher proportion of obligate seeders are more fire sensitive and more susceptible to the effects of inappropriate fire regimes (e.g. too frequent fire). This is because being killed by fire and relying on seed for regeneration, obligate seeders may experience population decline or localised extinction if the fire interval is shorter than the time taken to reach reproductive maturity and develop an adequate seed bank[7,8] (see also Section 2.1 of *Bushfire impacts — A national model for assessing local landscape restoration priorities*).

Consequently, obligate seeder species are more likely to be missing from burnt sites, especially if they have a history of frequent fires and/or other stressors such as drought leading up to the fire event (due to the negative effect of drought on seed production).

This is where knowledge of plant traits such as fire response can help to identify species that are more likely to require management intervention to ensure persistence of a particular reference community. It is these community components that can be targeted for post-fire assessment and potential targeted seed use to assist recovery.

> **In *Bushfire impacts — A national model for assessing local landscape restoration priorities* we outlined a staged approach that aims to minimise seed input through targeted seed use.**

This is important given the generally limited supply of seed (especially for threatened ecological communities) and that restoration activities aim to maximise the efficient and effective use of seed. This approach advocates interventions that work with, and enhance, the regenerative capacity of a community before seed inputs are considered. This means that facilitated regeneration is undertaken first to test regenerative capacity. If species are still missing, then targeted seed inputs are considered.

However, this approach recognises that, due to management prior to fire, historical fire regimes and other disturbances, seed inputs may be required to maintain a particular reference community composition. Here, targeted seed use — in combination with other management activities — can specifically focus on groups or species with minimal regeneration within a community context.

1.2 Aims and objectives

The aim of this report is to outline broad potential seedling addition estimates for five TECs representing lower and upper scenarios for restoration. Recognising that targeted seed inputs will predominately relate to fire sensitive species, this report will specifically focus on representative fire sensitive obligate seeders. The specific aims are to:

- Following *Bushfire impacts — A national model for assessing local landscape restoration priorities*, broadly outline the circumstances where seed, seedling and/or propagule addition may be required in fire affected vegetation communities, focusing on fire sensitive (obligate seeder) species.
- Present general seedling addition rates for each community type and TEC for different life form groups (i.e. trees, shrubs and herbaceous).
- Provide potential estimates of seedling requirements for a range of scenarios from reintroducing 10% of the fire sensitive species through to 100% reintroduction of fire sensitive species.
- Apply these estimates to specific examples of fire sensitive species (obligate seeders) within each TEC.

These broad estimates can be used to develop medium and long-term responses to post-fire recovery for a range of uses including habitat restoration, targeted reintroduction and/or increasing quantities of native seed in seed banks.

General estimates of potential seed requirements are essential to the native seed industry to enable forward planning for seasonal collection and to maximise the likelihood of restoration success through adequate species and genetic diversity both now and in the future.

2 RESTORATION APPROACHES AND SEED NEEDS

2.1 Targeted seed inputs in bushfire recovery

Following the 2019–20 fires, there were many questions about the role and need for seed inputs as part of bushfire recovery and how this may vary between different vegetation community types. In *Bushfire impacts — A national model for assessing local landscape restoration priorities*, we outlined a framework that combines plant trait information with the degradation spectrum and site variables (that may reduce regenerative capacity) to understand what, if any, intervention is required. Information on plant traits is essential for identifying the species that may be more sensitive to fire (and inappropriate fire regimes) so that seed can be used most efficiently and effectively.

In tandem, the restoration spectrum recognises that sites vary in the degree of damage or degradation and therefore the level of management intervention required, especially in relation to the necessary seed inputs (Figure 2.1-1). Taken together this information can be used to assess the need for targeted seed inputs in bushfire recovery.

For all restoration approaches, we use the typology outlined within the recently revised SERA standards.[4]

At the lower end of the degradation spectrum are sites that require protection/natural regeneration.

These sites have a high potential for natural regeneration and no restoration intervention is usually required. However, as with all restoration approaches across the spectrum, ongoing threatening processes need to be mitigated to maintain habitat condition.

The next restoration approach is facilitated regeneration (*synonym:* assisted regeneration).

Seed input is generally not required due to the high potential for natural regeneration (although there may be exceptions for threatened species conservation or other special case seed input). Other management activities such as weed control may be implemented to facilitate and secure natural regeneration.

A combined regeneration/reintroduction approach is applied to sites where there is potential for natural regeneration, but seed addition is considered for some specific non-regenerating species and/or functional groups (Figure 2.1-1).

These reintroduced elements will depend on the adequate availability of propagules and may provide specific habitat functions, be critical structural elements and/or be of high conservation significance. This combined approach is often undertaken sequentially, with facilitated regeneration activities initiated first to provide an assessment of the underlying regenerative potential before seed addition is considered. Management to mitigate ongoing threatening processes is essential to support regeneration and ensure the effective use of seed resources.

Reconstruction is the restoration approach that requires the greatest seed input (Figure 2.1-1).

This approach is implemented in sites with few if any remaining native species and hence minimal natural regeneration potential. These sites usually have the highest damage due to pre-existing degradation and frequently require a combination of broad seed input and ongoing threat management.

The goals and details of each of these restoration approaches are outlined in **Table 2.1-1**.

This report focuses on the two restoration approaches that require seed, plants and/or propagules to assist bushfire recovery towards a *particular reference community*:

- combined regeneration/reintroduction and
- reconstruction (See **Table 2.1-1**).

However, as outlined in *Bushfire impacts — A national model for assessing local landscape restoration priorities*, it is likely extremely rare that there will no post-fire regeneration and that reconstruction (close to 100% replacement) would be required (i.e. the need to restore non-regenerating patches).

Instead, we include and highlight this restoration approach given its importance as a potential means of increasing the resilience of a vegetation community across the landscape by:

- extending the spatial extent of current patches and/or building buffers around existing vegetation communities
- establishing new populations and communities in strategic locations to improve connectivity between remnants and
- creating insurance populations for future fire events.

The following sections on seedling estimates relate to the first restoration approach: combined regeneration/reintroduction.

Figure 2.1-1. The spectrum of interventions from Protection/Natural regeneration, through to Assisted natural regeneration to Combined regeneration/reintroduction and Reconstruction in relation to the spectrum of habitat damage/degradation and seed input requirements. For all interventions, threat management is required to mitigate threatening processes. The green box above highlights the restoration interventions that require some seed and/or seedling (propagule) input. For combined regeneration/reintroduction, this will be the targeted introduction of non-regenerating groups: for fire this is usually fire sensitive species (obligate seeders) due to a history of inappropriate fire frequency. For reconstruction, this will be broad seed inputs to reintroduce a broad range of species and functional groups. This will be unlikely for fire affected communities but could be used more broadly in bushfire recovery to establish insurance populations, extend current patch size (e.g. into adjacent cleared areas), build buffers and improve connectivity across the landscape.

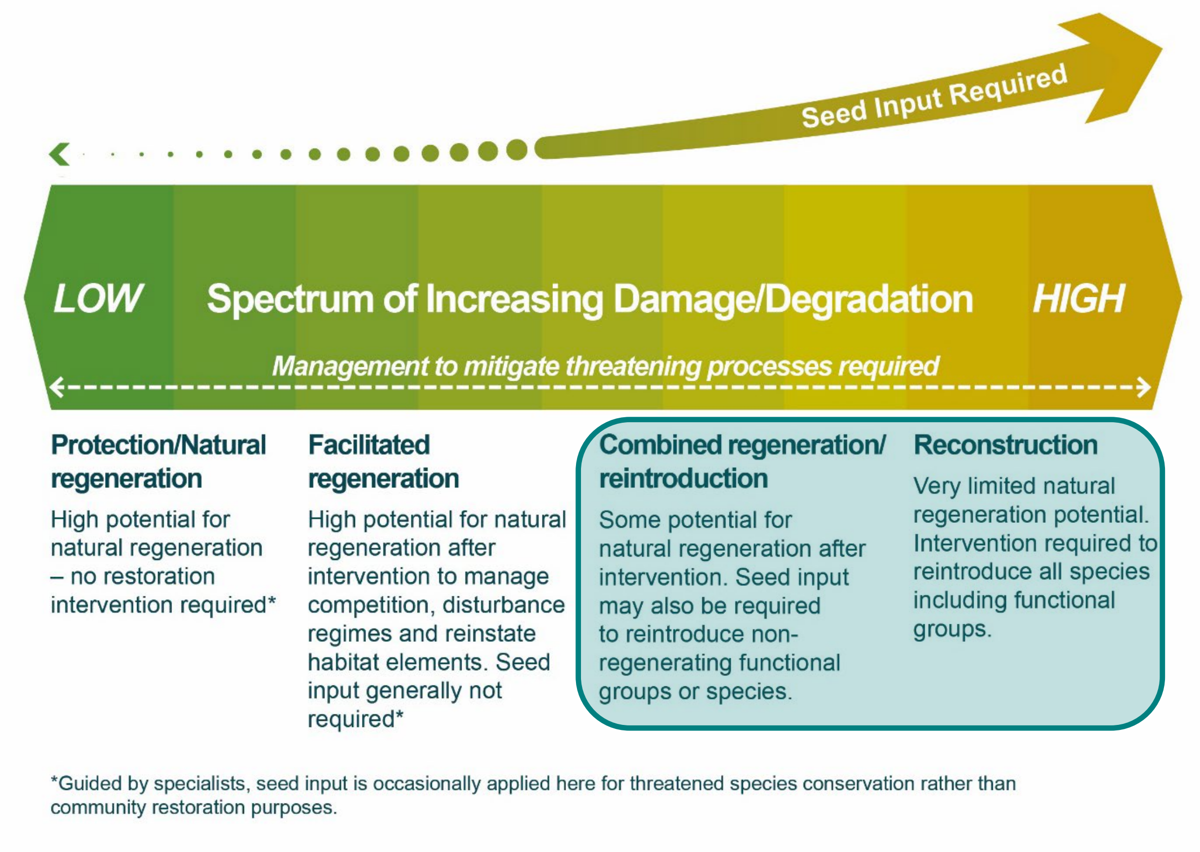


TABLE 2.1-1. THE GOALS AND DETAILS OF RESTORATION APPROACHES FOR BUSHFIRE-AFFECTED VEGETATION COMMUNITIES. IN THIS REPORT, WE FOCUS ON COMBINED REGENERATION/REINTRODUCTION AND RECONSTRUCTION WHICH REQUIRE SEED, PLANT AND/OR PROPAGULE INPUT.

RESTORATION APPROACH	PROTECTION/ NATURAL REGENERATION	FACILITATED NATURAL REGENERATION	COMBINED REGENERATION / REINTRODUCTION	RECONSTRUCTION
GOALS AND DETAILS	• Manage threats	• Weed removal to facilitate regeneration	• Weed removal • Facilitate recovery of fire sensitive species that are more likely to be affected by inappropriate fire regimes • Site assessments are required to evaluate and quantify missing species and/or functional groups • These assessments need to be undertaken in the right season and after sufficient post-fire rainfall • Targeted reintroduction of missing components • Use a staged approach that considers facilitated natural regeneration first before plant and/or seed addition	• Restore non-regenerating patches • Extend current patches and build buffers • Improve connectivity between remnants • Create insurance populations

2.2 Regeneration/reintroduction: estimating broad seed/seedling inputs

2.2.1 Limitations associated with seed/seedling estimates

Broad estimates of seed/seedling requirements for each community post-fire can be obtained using information on:

- species composition and fire response of those species, and
- the plant densities commonly used in restoration for each community type.

It is essential to note that these estimates are general and are not intended to be indicative of the precise need for restoration in bushfire-affected areas. Precise estimates of seed and/or seedling requirements can only be obtained by undertaking site assessments of these areas and quantification of any missing species and/or functional groups. This data would then be used to evaluate if species in these groups are regenerating post-fire and if a combined regeneration/reintroduction approach is required and/or appropriate.

We also strongly advocate for a staged approach to reintroduction, where facilitated regeneration is applied first as a means of testing natural regenerative capacity. If there are still non-regenerating species (after adequate time and rainfall, and surveys in the right season) then reintroduction can be considered. Additionally, given the absence of site-specific data, these estimates do not consider variation in abundance of species and/or spatial variation in dominant components.

Consequently, estimates should only be used to provide a general approximation of the potential demand for seedlings for restoration under a range of scenarios so that the native seed sector can prepare for current and future restoration needs.

There are several other considerations and caveats when estimating potential seedling numbers for bushfire-affected communities:

- The seedling density estimates provided here are not indicative of the starting state densities that may be observed during post-fire natural regeneration, which are likely to be much higher due to a pulse of post-disturbance recruitment. Instead, the estimates provided here are based on restoration/revegetation seedling addition density estimates which are generally much lower. Given that plant densities change over time in response to post-disturbance population and community dynamics, these estimates are intended to reflect a semi-mature to mature vegetation state.
- These estimates do not account for variation and potential loss due to seed viability, germination rates and/or low establishment success.
- To estimate the seed/seedlings required post-fire, we focus on fire sensitive obligate seeders; however, it is important to recognise two limitations of this approach. Firstly, the species list for each community is not definitive and may include other species not listed here. We, therefore, assume that the proportion of obligate seeders, resprouters and facultative species in this list for each life form group (trees, shrubs, herbaceous and climbers/vines) is generally representative of the broader community.

  Secondly, information on fire response may be limited for some communities. Consequently, our fire response data (obtained from the literature — see Section 7.7 in *Bushfire impacts — A national model for assessing local landscape restoration priorities*) is based on the best information currently available but is likely to be refined by assessment of species' responses from the 2019–20 fires.
- In the absence of site assessments to quantify seed requirements for each TEC, we apply an approach that gives a range of seed estimates from 10% of the fire sensitive plants of each life form requiring reintroduction (low intervention) through to 100% of fire sensitive plants requiring reintroduction (worst case scenario). This approach is applied because the patchy nature of fire intensity and fire interval means that levels of regeneration are often spatially variable and not uniform across fire affected areas.

For example, limited regeneration will likely only occur in smaller patches that have been burnt more frequently and at a higher intensity, whereas patches with more appropriate fire histories and lower fire intensity may have adequate regeneration. These estimates are therefore intended to present a range of values across a potential intervention spectrum.

- Even with concurrent weed management through facilitated regeneration, planting densities may have to be increased to assist ongoing weed suppression. For example, higher planting densities may be required to provide resistance to weed re-invasion and to facilitate establishment success of natives.

2.2.2 Methods to estimate potential seedling input for fire sensitive species

Quantifying seedling rates is a critical step in assessing the quantity of seed required to assist bushfire recovery. Due to species-specific responses, there are many complexities in understanding the amount of seed required to obtain seedling numbers for each species. Consequently, refining the quantity of seed for each community will require an assessment of the quality attributes (e.g. among taxa variation in seed viability and germinability) of seed lots of the individual species.

Collecting this species-specific information was beyond the scope of this project, so we focus on seedling densities rather than seed. In some cases, hand-seeding may be considered for targeted reintroduction if enough seed is available for a particular species and there is sufficient information on seed requirements.

This report focuses on targeted seed inputs of fire sensitive species. As such we only consider estimates of seedling requirements for fire sensitive taxa of each life form.

We also recognise that any targeted inputs in bushfire-affected areas will be undertaken within the context of surrounding natural regeneration and — depending on the timing of intervention post-fire — may not necessarily include suitable regeneration niches. Consequently, seedlings may be the most appropriate form of targeted plant input and successful establishment could require additional activities (e.g. small scale site preparation or establishment of restoration nodes) that are not explicitly considered here.

The general equation to estimate the number of seedlings of fire sensitive species per hectare (ha^{-1}) for each life form group is:

$$N = [\%FireSen \times \%Reintro] \times FullRecon \qquad [1]$$

Where:

N	=	the number of seedlings required per hectare
%FireSen	=	the per cent of the life form category that are fire sensitive
%Reintro	=	the per cent of the life form category that requires reintroduction
FullRecon	=	full reconstruction rate of seedlings per hectare (number of seedlings ha^{-1} if all strata and life forms are considered — this is the baseline estimate of seedlings for full reconstruction)

2.2.3 Data collection methods

To estimate required seedling inputs, we undertook literature searches across national recovery plans, peer-reviewed journal articles and books and revegetation guidelines to obtain plant density information and restoration densities for each community. Where possible, we verified and supplemented published data with personal communication with key researchers, managers and practitioners from a range of organisations.

Key searches included specific species within each TEC, TEC level data and, where required, were extended to community type natural vegetation densities.

3 SEEDLING ESTIMATES FOR REPRESENTATIVE THREATENED ECOLOGICAL COMMUNITIES

3.1 Threatened Ecological Communities (TEC)

To provide general estimates of potential seedling inputs for a range of restoration scenarios for fire sensitive species, we consider five TECs that are representative of different vegetation types (see **Table 3.1-1**).

For each community, we present broad estimates of potential seedling addition based on a range of scenarios: from 10% reintroduction of obligate seeders through to all obligate seeders (100%) requiring reintroduction (see **Table 3.1-2**); however, we recognise that this is an arbitrary range and should be used as indicative only. It is also very unlikely that all obligate seeders will require intervention (see limitations discussed in Section 2.2.1) and so 100% reintroduction is presented purely as a worst case scenario upper bound.

TABLE 3.1-1. THE VEGETATION COMMUNITY TYPE, LOCATION AND ABBREVIATION OF FIVE OF THE TECS WITH >10% OF THEIR ESTIMATED DISTRIBUTION WITHIN THE AREAS BURNT IN THE 2019–20 FIRES. FOR FURTHER DETAILS SEE *BUSHFIRE IMPACTS — A NATIONAL MODEL FOR ASSESSING LOCAL LANDSCAPE RESTORATION PRIORITIES*.

THREATENED ECOLOGICAL COMMUNITY (TEC)	ABBREVIATION	COMMUNITY TYPE	STATE
Lowland Rainforest of Subtropical Australia	LROSA	Rainforest	QLD/NSW
Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion	UBEFS	Wet Sclerophyll	NSW
Lowland Grassy Woodland in the South East Corner Bioregion	LGWSEC	Grassy Woodland	NSW
Silurian Limestone Pomaderris Shrubland of the South East Corner and Australian Alps Bioregions	SLPS	Shrubland	VIC
Eastern Stirling Range Montane Heath and Thicket	ESRMHT	Heathland	WA

Table 3.1-2. A summary of the seedling estimates (plants ha^{-1}) for each of the five TECs for each life form (Tree, Shrub and Herbaceous) based on a range from 10% of obligate seeders requiring reintroduction, through to 100% of obligate seeders requiring reintroduction. For details of the calculation for each TEC see Sections 3.2–3.6.

TEC	RESTORATION APPROACH	LIFE FORM (TREE, SHRUB OR HERBACEOUS)	SEEDLING ESTIMATES (PLANTS HA^{-1}) BASED ON THE % OF OBLIGATE SEEDERS THAT MAY REQUIRE REINTRODUCTION (RANGE: 10% TO 100% OF OBLIGATE SEEDERS)
LROSA	Combined regeneration/ reintroduction	Tree	61–606
LROSA	Combined regeneration/ reintroduction	Shrub	66–658
LROSA	Combined regeneration/ reintroduction	Herbaceous	333–3,333
UBEFS	Combined regeneration/ reintroduction	Shrub	32–317
UBEFS	Combined regeneration/ reintroduction	Herbaceous	250–2,500
LGWSEC	Combined regeneration/ reintroduction	Tree	0–3
LGWSEC	Combined regeneration/ reintroduction	Shrub	10-100
LGWSEC	Combined regeneration/ reintroduction	Herbaceous	7,359–73,590
SLPS	Combined regeneration/ reintroduction	Shrub	125–1,250
SLPS	Combined regeneration/ reintroduction	Herbaceous	139–1,389
ESRMHT	Combined regeneration/ reintroduction	Shrub	202–2,018
ESRMHT	Combined regeneration/ reintroduction	Herbaceous	132–1,317

Table 3.1-3: The broad number of seedlings (plants ha^{-1}) required for full reconstruction (100% reintroduction) for different life form groups (trees, shrubs and herbaceous) for the five TECs representing different vegetation types. These seedling density estimates are general and intended to be indicative of planting densities in relation to the potential seedling requirements for reintroduction of each life form group. See Section 2.2.1 for a full discussion of the limitations of estimating seedling requirements for post-fire recovery.

TEC	LROSA		UBEFS		LGWSEC		SLPS		ESRMHT	
LIFE FORM	Reconstruction (100% reintroduction)		Reconstruction (100% reintroduction)		Reconstruction (100% reintroduction)		Reconstruction (100% reintroduction)		Reconstruction (100% reintroduction)	
	Plant spacing (m)	Number of plants ha^{-1}	Plant spacing (m)	Number of plants ha^{-1}	Plant spacing (m)	Plant spacing (m)	Number of plants ha^{-1}	Plant spacing (m)	Number of plants ha^{-1}	Plant spacing (m)
Trees	1.8	3,086	2	2,500	>10	1.8	3,086	2	2,500	>10
Shrubs	1.5	4,444	1.5	4,444	5[2]	1.5	4,444	1.5	4,444	5[2]
Herbaceous	1.0	10,000	1.0	10,000	<0.5	1.0	10,000	1.0	10,000	<0.5

[1] For Grassy Woodlands it is important that trees are not planted at greater densities than that of the original woodland community (30–40 trees ha^{-1}, but for some systems, this can range from 64–231 trees ha^{-1} (e.g.[9]) To account for potential mortality (especially in degraded sites) this number could be increased, but it is essential to aim for the original densities in the reference community. It is therefore advisable to take a staged approach and undertake infill planting later if survival is low, rather than initially planting high densities.

[2] For Grassy Woodlands shrubs distribution may be patchy and spatially variable but the spacing of 5m represents an average across the site to provide broad estimates of plants ha^{-1}.

Sources:

LROSA: Peel (2010), Catterall and Harrison (2006), Greening Australia (2012), Catterall and Kanowski (2010), Chenoweth EPLA and Bushland Restoration Services (2012).[10–14]

UBEFS: Cooper (1998)[15] and plant density estimates were based on the best available general information on Wet Sclerophyll Eucalypt communities

LGWSEC: Rawlings *et al.* (2010), Cuneo *et al.* (2018),Lindenmayer *et al.* (2014)[16–18]

SLPS: No specific sources available so plant density estimates were based on best available general information on shrubland communities

ESRMHT: Keith *et al.* (2014), Barrett and Yates (2015), Rathbone and Barrett (2017)[19–21]

3.2 Lowland Rainforest (LROSA)

3.2.1 Description

The Lowland Rainforest of Subtropical Australia (LROSA) ecological community is located two kilometres inland of Australia's eastern coast in the New South Wales North Coast and South Eastern Queensland bioregions.[22] It typically occurs between Maryborough, Queensland in the north and Clarence River, New South Wales in the south. Additional isolated patches can be found between the Clarence River and Hunter River.

Key characteristic features include high annual rainfall of more than 1,300mm/year and low-lying altitudes generally below 300m above sea level.[22] The closed tree canopy cover commonly includes booyong (*Argyrodendron trifoliolatum*) and fig trees and contains relatively few she-oaks (*Casuarina*), tea-trees (*Melaleuca*) and gum trees (*Eucalyptus*).

Canopy species richness usually is very high with more than 30 native woody species per patch but can also be heavily dominated by a single species.[22] Ferns and vines are abundant and diverse, including wonga vine (*Pandorea floribunda*), lawyer vine (*Calamus muelleri*) and bird's nest fern (*Asplenium nidus*). Although these species are common in LROSA, species composition varies between regions and local areas.

The majority of species are resprouters (35%, see **Figure 3.2-1**) with few obligate seeders (16%) and less facultative seeders (8%). Trees make up almost half of the flora species (47%), while shrubs and climbers/vines represent 23% and 20%, respectively. The proportion of obligate seeders is highest in the tree (20%) and herbaceous (33%) life form groups, and lowest in shrubs (15%) (**Figure 3.2-1**).

FIGURE 3.2-1. A SUMMARY OF THE COMMUNITY COMPOSITION, LIFE FORM AND FIRE RESPONSE OF SPECIES FROM THE LOWLAND RAINFOREST OF SUBTROPICAL AUSTRALIA. RS = RESPROUTERS, OS = OBLIGATE SEEDERS, FS = FACULTATIVE SEEDERS, UN = UNKNOWN.

Community Characteristics

Number of species:
- 119 [106 genera]

Trees:
- 47% (n = 56)

Shrubs:
- 23% (n = 27)

Herbaceous:
- 10% (n = 12)

Climbers/Vines:
- 20% (n = 24)

Fire Response

Resprouters:
- 35% (n = 42)

Obligate seeders:
- 16% (n= 19)

Number of Obligate seeders of each life form

Life form	OS
Herbaceous	4
Shrub	4
Tree	11
Climber/Vine	0
Total (n)	19

Facultative seeders:
- 8% (n = 10)

Geophytes:
- 1% (n = 1)

Unknown:
- 40% (n = 47)

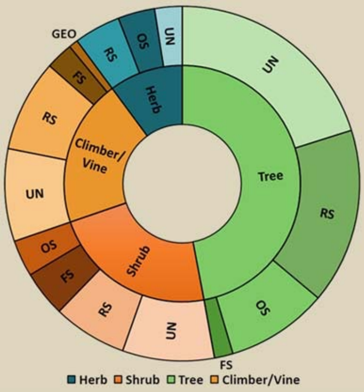
Life Form and Fire Response

Resprouters (RS):
- Ranged from 30% of shrubs to 42% of herbaceous species

Obligate seeders (OS):
- Higher proportion of trees (19%) and herbaceous species (33%)

Facultative seeders (FS):
- Higher proportion of shrubs (18%) and climbers/vines (12%)

For each life form:
- High proportion of unknown (UN) fire responses (25-43% of species)



3.2.2 Restoration scenarios

As discussed in Section 2.1, there are four approaches to restoration of fire affected vegetation communities: from protection/natural regeneration through to reconstruction. For the estimates of seedlings for the Lowland Rainforest, we focus on seedling estimates for the combined regeneration/reintroduction approach with an emphasis on obligate seeders.

TABLE 3.2-1. RESTORATION APPROACHES FOR LOWLAND RAINFOREST

RESTORATION APPROACH	PROTECTION/ NATURAL REGENERATION	FACILITATED NATURAL REGENERATION	COMBINED REGENERATION / REINTRODUCTION	RECONSTRUCTION
GOAL	• **Manage threats**	• **Weed removal (especially transformer weeds) to facilitate regeneration**	• **Weed removal (especially transformer weeds)** • **Facilitate recovery of fire sensitive species**	• **Build buffers around rainforest remnants** • **Extend the spatial extent of current patches** • **Improve connectivity between remnants**
DETAILS AND/OR TARGET SPECIES	**Manage threats** • Clearing from rural, agricultural and urban development • Invasion and establishment of transformer weed species • Inappropriate fire regimes • Impacts associated with remnant fragmentation	**Manage threats** (see Protection) **Weed removal.** Key weeds include: • *Anredera cordifolia* (Madeira Vine) • *Asparagus plumosus* (Climbing Asparagus) • *Cinnamomum camphora* (Camphor Laurel) • *Ipomoea spp.* (Morning Glory) • *Ligustrum sinense* (Small-leaved Privet) • *Macfadyena unguis-cati* (Cats Claw Creeper) • *Ochna serrulata* (Ochna) • *Passiflora subpeltata* (White Passionflower) • *Solanum mauritianum* • *Tradescantia fluminensis*	**Weed removal** (see Facilitated regeneration) **Reintroduction:** • Site assessments are required to evaluate and quantify missing species and/or functional groups • Fire sensitive species (obligate seeders) are more likely to be affected by inappropriate fire regimes • Obligate seeders are listed in Table 3.2-2. • Due to the extent of impact, fire affected taxa may require management intervention in terms of seed and/or seedling addition (see Table 3.2-2).	• Requires broad seed inputs • Conservation planning can identify where in the landscape these are positioned to maximise benefits to biodiversity, genetic connectivity and as protection from future fire events

3.2.3 Broad estimates of seedling needs

3.2.3.1 Combined regeneration/reintroduction

Estimates of seedling requirements for tree reintroduction post-fire

For Lowland Rainforest, trees make up the highest proportion of the community (47%, n = 56/119), with 11 of the 56 tree species (19.64%) classified as obligate seeders (see **Figure 3.2-1**). This suggests that ~20% of the tree strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 19.64% = 0.1964) require reintroduction, and the full reconstruction rate is 3,086 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 61 tree seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.1964 \times 0.1] \times 3086$$

$$N = 0.01964 \times 3086$$

$$N = 61\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 19.64% = 0.1964) require reintroduction, and the full reconstruction rate is 3,086 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 606 tree seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.1964 \times 1.0] \times 3086$$

$$N = 0.1964 \times 3086$$

$$N = 606\ seedlings\ ha^{-1}$$

This provides a range of 61–606 tree seedlings ha^{-1}

Estimates of seedling requirements for shrub reintroduction post-fire

For Lowland Rainforest, shrubs make up a smaller proportion of the community (23%, n = 27/119), with 4 of the 27 shrub species (14.81%) classified as obligate seeders (see Figure 3.2-1). This suggests that ~15% of the shrub strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 14.81% = 0.1481) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 66 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.1481 \times 0.1] \times 4444$$

$$N = 0.01481 \times 4444$$

$$N = 66\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 14.81% = 0.1481) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 658 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.1481 \times 1.0] \times 4444$$

$$N = 0.1481 \times 4444$$

$$N = 658\ seedlings\ ha^{-1}$$

This provides a range of 66–658 shrub seedlings ha^{-1}

Estimates of seedling requirements for herbaceous reintroduction post-fire

Herbaceous species constitute the smallest percentage of the community (10%) with four of the 12 (33.33%) herbaceous species classified as obligate seeders (see **Figure 3.2-1**). This suggests that ~33% of the herbaceous strata may be fire sensitive.

- If 10% (%Reintro = 0.1) of the fire sensitive species (%FireSen = 33.33% = 0.3333) require reintroduction, and the full reconstruction rate is 10,000 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 333 herbaceous seedlings would be required ha^{-1} (see general equation above and example equation below).

$$N = [0.3333 \times 0.1] \times 10000$$

$$N = 0.03333 \times 10000$$

$$N = 333\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 1.0) of the fire sensitive species (%FireSen = 33.33% = 0.3333) require reintroduction, and the full reconstruction rate is 10,000 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 3,333 herbaceous seedlings would be required ha^{-1} (see general equation above and example equation below).

$$N = [0.3333 \times 1.0] \times 10000$$

$$N = 0.3333 \times 10000$$

$$N = 3333\ seedlings\ ha^{-1}$$

This provides a range of 333–3,333 herbaceous seedlings ha^{-1}

Obligate seeder shrubs are highly represented within the fire affected species (see **Table 3.2-2**). However, given their low abundance and restricted distribution within this community, there is currently insufficient information to provide even general estimates on the seedling requirements to assist post-fire recovery. We therefore highly recommend targeted field surveys for these species in priority areas but include them here to highlight the potential need for post-fire intervention for these species in the form of combined regeneration and targeted seed inputs.

Table 3.2-2. A list of the fire sensitive species (obligate seeders (OS)) from the Lowland Rainforest of Subtropical Australia TEC species list and the fire affected species within the TEC 'likely to occur' boundary. Life form: Herbaceous (H), Shrub (S), Tree (T), Climber/Vine (C). Seed storage: Soil (S), Transient (T), Canopy (C), Unknown (UN).

IDENTIFICATION SOURCE	SCIENTIFIC NAME	LIFE FORM	FIRE RESPONSE	SEED STORAGE	MANAGEMENT INTERVENTION (EXPERT PANEL)
TEC species list	*Alphitonia petrei*	T	OS	UN	
TEC species list	*Archontophoenix cunninghamiana*	T	OS	T	
TEC species list	*Asplenium australasicum*	H	OS	T	
TEC species list	*Caldcluvia paniculosa*	T	OS	UN	
TEC species list	*Cinnamomum oliveri*	T	OS	UN	
TEC species list	*Citronella moorei*	T	OS	UN	
TEC species list	*Dendrocnide excelsa*	T	OS	S	
TEC species list	*Ehretia acuminata*	T	OS	T	
TEC species list	*Elaeodendron australe*	S/T	OS	UN	
TEC species list	*Litsea reticulata*	T	OS	UN	
TEC species list	*Platycerium spp.*	H	OS	UN	
TEC species list	*Plectranthus spp.*	H	OS	UN	
TEC species list	*Polyscias elegans*	T	OS	S	
TEC species list	*Pyrrosia spp.*	H	OS	UN	
TEC species list	*Sarcomelicope simplicifolia*	S/T	OS	T	
TEC species list	*Sloanea australis*	T	OS	UN	
TEC species list	*Sloanea woollsii*	T	OS	S	
TEC species list	*Streblus brunonianus*	S/T	OS	T	
TEC species list	*Trema aspera*	S/T	OS	S	
Fire affected species	*Acacia cangaiensis*	S	OS	UN	Yes
Fire affected species	*Acacia tessellata*	S	OS	UN	Yes
Fire affected species	*Bertya sp. Clouds Creek (M.Fatemi 4)*	S	OS	S	Yes
Fire affected species	*Cestichis reflexa*	H	OS	UN	
Fire affected species	*Grevillea acanthifolia subsp. paludosa*	S	OS	S	Yes
Fire affected species	*Hibbertia villosa*	S	OS	UN	Yes
Fire affected species	*Kardomia prominens*	S	OS	UN	Yes
Fire affected species	*Persoonia rufa*	S	OS	S	Yes
Fire affected species	*Philotheca obovatifolia*	S	OS	UN	Yes
Fire affected species	*Pomaderris ligustrina subsp. latifolia*	S	OS	T	Yes
Fire affected species	*Prostanthera saxicola var. major*	S	OS	S	Yes
Fire affected species	*Zieria floydii*	S	OS	UN	Yes
Fire affected species	*Zieria lasiocaulis*	S/T	OS	S	Yes

3.3 Upland Basalt (UBEFS)

3.3.1 Description

The Upland Basalt Eucalypt Forest of the Sydney Basin Bioregion is located in parts of the Southern Tablelands, Southern Highlands and the Blue Mountains of south-eastern New South Wales.[23] It occurs typically in the Sydney Basin Bioregion between Denman in the north, down to Yadboro in the south.

Key characteristic features include the canopy of tall eucalypt trees and an understorey comprising of diverse native shrubs, herbs, vines, grasses and ferns. The UBEF generally occurs at higher altitudes (more than 650m above sea level) with high rainfall (1,000–1,800mm/year) on volcanic substrates (such as basalt).[23,24]

The community structure does vary, however, from tall open forests with 30m tall trees to woodland with 10–30m tall trees.[25] These changes depend on the slope, aspect, soil condition and depth, as well as prior disturbance and/or clearing.

The majority of species are resprouters (44%, see **Figure 3.3-1**) with few facultative seeders (29%) and fewer obligate seeders (17%). Herbaceous species make up over half of the flora species (51%) and shrubs, trees and climbers/vines have relatively similar abundances (18%, 17% and 14%, respectively). The proportion of obligate seeders is highest in the herbaceous group (25%) and lowest in shrubs (15%). No trees were classified as obligate seeders (**Figure 3.3-1**).

FIGURE 3.3-1. A SUMMARY OF THE COMMUNITY COMPOSITION, LIFE FORM AND FIRE RESPONSE OF SPECIES FROM THE UPLAND BASALT EUCALYPT FOREST. RS = RESPROUTERS, OS = OBLIGATE SEEDERS, FS = FACULTATIVE SEEDERS, UN = UNKNOWN.

Community Characteristics

Number of species:
- 78 [60 genera]

Trees:
- 17% (n = 13)

Shrubs:
- 18% (n = 14)

Herbaceous:
- 51% (n = 40)

Climbers/Vines:
- 14% (n = 11)

Fire Response

Resprouters:
- 44% (n = 34)

Obligate seeders:
- 17% (n= 13)

Life form	OS
Herbaceous	10
Shrub	1
Tree	0
Climber/Vine	2
Total (n)	13

Facultative seeders:
- 29% (n = 23)

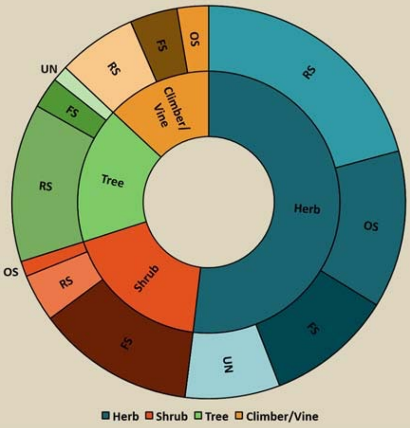
Unknown:
- 10% (n = 8)

Life Form and Fire Response

Resprouters (RS):
- Ranged from 22% of shrubs to 77% of trees

Facultative (FS) and Obligate (OS) seeders:
- 71% of shrubs are facultative seeders, only 7% are obligate seeders
- Herbaceous species had similar proportions of obligate seeders (25%) and facultative seeders (20%)

For each life form:
- Low proportion of unknown (UN) fire responses (0-15% of species)



3.3.2 Restoration scenarios

As discussed in Section 2.1, there are four approaches to the restoration of fire affected vegetation communities: from protection/natural regeneration through to reconstruction. For the estimates of seedlings for Upland Basalt Eucalypt Forest, we focus on the combined regeneration/reintroduction approach with an emphasis on obligate seeders.

TABLE 3.3-1. RESTORATION APPROACHES FOR UPLAND BASALT EUCALYPT FOREST

RESTORATION APPROACH	PROTECTION/ NATURAL REGENERATION	FACILITATED NATURAL REGENERATION	COMBINED REGENERATION / REINTRODUCTION	RECONSTRUCTION
GOAL	• **Manage threats**	• **Weed removal to facilitate regeneration**	• **Weed removal** • **Facilitate recovery of fire sensitive species**	• **Restore non-regenerating patches** • **Extend current patches and build buffers** • **Improve connectivity between remnants**
DETAILS AND/OR TARGET SPECIES	**Manage threats** • Clearing of land for urban, rural and agricultural development • Fragmentation and edge effects • Grazing by stock • Fertiliser and herbicide use on adjacent farmland • Improper recreational use e.g. informal trail forming, rubbish dumping, trampling, visitation of cats and dogs, firewood collection • Inappropriate fire regimes • Invasion by weeds and feral animals • Climate change • Potential future quarrying and mining	**Manage threats** (see Protection) **Weed removal**. Key weeds include: • *Asparagus asparagoides* (Bridal Creeper) • *Berberis vulgaris* (Barberry) • *Genista spp.* (Broom) • *Hedera helix* (English Ivy) • *Ilex aquifolium* (English Holly) • *Lonicera japonica* (Japanese Honeysuckle) • *Nassella spp.* • *Pyracantha spp.* (Firethorn) • *Rubus fruticosus aggregate* (Blackberry)	**Weed removal** (see Facilitated regeneration) **Reintroduction**: • Site assessments are required to evaluate and quantify missing species and/or functional groups • Fire sensitive species are more likely to be affected by inappropriate fire regimes • Obligate seeders are listed in Table 3.3-2 • Due to the extent of impact, fire affected taxa may require management intervention in terms of seed and/or seedling addition (see Table 3.3-2).	• Requires broad seed inputs • Conservation planning can identify where in the landscape these are positioned to maximise benefits to biodiversity, genetic connectivity and as protection from future fire events

3.3.3 Broad estimates of seed needs

3.3.3.1 Combined regeneration/reintroduction

Estimates of seedling requirements for herbaceous reintroduction post-fire

For Upland Basalt Eucalypt Forest, herbaceous species make up the highest proportion of the community (51%, n = 40/78), with 10 of the 40 herbaceous species (25%) classified as obligate seeders (see **Figure 3.3-1**). This suggests that ~25% of the herbaceous strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 25% = 0.25) require reintroduction, and the full reconstruction rate is 10,000 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 250 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.25 \times 0.1] \times 10000$$

$$N = 0.025 \times 10000$$

$$N = 250\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 25% = 0.25) require reintroduction, and the full reconstruction rate is 10,000 seedlings ha^{-1} (FullRecon, see **Table 3.1-3)**, then approximately 2,500 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.25 \times 1.0] \times 10000$$

$$N = 0.25 \times 10000$$

$$N = 2500\ seedlings\ ha^{-1}$$

This provides a range of 250–2,500 herbaceous seedlings ha^{-1}

Estimates of seedling requirements for shrub reintroduction post-fire

Shrubs constitute a smaller percentage of the community (18%), with one of the 14 (7.14%) shrub species classified as obligate seeders (see **Figure 3.3-1**). This suggests that ~7% of the shrub strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 7.14% = 0.0714) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 32 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.0714 \times 0.1] \times 4444$$

$$N = 0.00714 \times 4444$$

$$N = 32\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 7.14% = 0.0714) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 317 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.0714 \times 1.0] \times 4444$$

$$N = 0.0714 \times 4444$$

$$N = 317\ seedlings\ ha^{-1}$$

This provides a range of 32–317 shrub seedlings ha^{-1}

TABLE 3.3-2: A LIST OF THE FIRE SENSITIVE SPECIES (OBLIGATE SEEDERS (OS)) FROM THE UPLAND BASALT EUCALYPT FORESTS OF THE SYDNEY BASIN BIOREGION TEC SPECIES LIST AND THE FIRE AFFECTED SPECIES WITHIN THE TEC 'LIKELY TO OCCUR' BOUNDARY. LIFE FORM: HERBACEOUS (H), SHRUB (S), TREE (T), CLIMBER/VINE (C). SEED STORAGE: SOIL (S), CANOPY (C), UNKNOWN (UN).

IDENTIFICATION SOURCE	SCIENTIFIC NAME	LIFE FORM	FIRE RESPONSE	SEED STORAGE	MANAGEMENT INTERVENTION (EXPERT PANEL)
TEC species list	*Acacia elata*	S	OS	S	
TEC species list	*Ajuga australis*	H	OS	UN	
TEC species list	*Austrocynoglossum latifolium*	H	OS	S	
TEC species list	*Centella asiatica*	H	OS	S	
TEC species list	*Clematis aristata*	C	OS	S	
TEC species list	*Marsdenia flavescens*	C	OS	UN	
TEC species list	*Plantago debilis*	H	OS	S	
TEC species list	*Poranthera microphylla*	H	OS	S	
TEC species list	*Pyrrosia rupestris*	H	OS	UN	
TEC species list	*Senecio linearifolius*	H	OS	S	
TEC species list	*Sigesbeckia orientalis subsp. orientalis*	H	OS	S	
TEC species list	*Stellaria flaccida*	H	OS	S	
TEC species list	*Urtica incisa*	H	OS	S	
Fire affected species	*Acacia clunies-rossiae*	S	OS	UN	Yes
Fire affected species	*Acacia hamiltoniana*	S	OS	UN	Yes
Fire affected species	*Banksia penicillata*	S	OS	C	Yes
Fire affected species	*Boronia subulifolia*	S	OS	UN	Yes
Fire affected species	*Cyphanthera scabrella*	S	OS	UN	Yes
Fire affected species	*Darwinia taxifolia subsp. macrolaena*	S	OS	S	Yes
Fire affected species	*Epacris gnidioides*	S	OS	UN	Yes
Fire affected species	*Eucalyptus fraxinoides*	T	OS	C	Yes
Fire affected species	*Grevillea aspleniifolia*	S	OS	S	Yes
Fire affected species	*Grevillea baueri subsp. asperula*	S	OS	S	Yes
Fire affected species	*Grevillea evansiana*	S	OS	S	Yes
Fire affected species	*Hakea constablei*	S	OS	C	Yes
Fire affected species	*Hakea dohertyi*	S	OS	C	Yes
Fire affected species	*Persoonia mollis subsp. budawangensis*	S	OS	S	Yes
Fire affected species	*Prostanthera saxicola var. montana*	S	OS	S	Yes
Fire affected species	*Zieria caducibracteata*	S/T	OS	UN	Yes
Fire affected species	*Zieria murphyi*	S	OS	S	Yes

3.4 Lowland Grassy Woodlands in the South East Corner (LGWSEC)

3.4.1 Description

The Lowland Grassy Woodlands in the South Eastern Corner Bioregion (LGWSEC) is located in New South Wales from the Araluen Valley to the Victoria border. It is largely fragmented, and most remnants have been modified including in the Bega and Cobargo valleys.[26]

Key characteristic features include undulating terrain with altitudes less than 500m above sea level and rain shadow areas (750–1100mm/year mean annual rainfall).[26] The community structure can vary between grassy woodland and a more open forest, altering with site size, drought conditions and recent disturbances.

Most of the diversity occurs in the ground layer grasses and herbs. The canopy layer is typically mature (up to 20m tall), dominated by forest red gum (*Eucalyptus tereticornis*) and/or white stringybark (*Angophora floribunda*) with 15–30% canopy cover. The mid layer is often open or sparse with a ground layer dominated by grasses and herbs. Common species include kangaroo grass (*Themeda triandra*), tussock grass (*Poa labillardieri*) and paddock lovegrass (*Eragrostis leptostachya*).

The majority of species are resprouters (52%, see **Figure 3.4-1**) with some facultative seeders (24%) and few obligate seeders (17%). Herbaceous species make up over three-quarters of the flora species (77%) and shrubs and trees similar abundances (8%, 11%, respectively). The proportion of obligate seeders is highest in the shrubs (25%) and herbaceous (18%) life form groups, and lowest in shrubs (6%).

FIGURE 3.4-1. A SUMMARY OF THE COMMUNITY COMPOSITION, LIFE FORM AND FIRE RESPONSE OF SPECIES FROM THE LOWLAND GRASSY WOODLAND. RS = REPROUTERS, OS = OBLIGATE SEEDERS, FS = FACULTATIVE SEEDERS, UN = UNKNOWN.

Community Characteristics

Number of species:
- 151 [99 genera]

Trees:
- 11% (n = 16)

Shrubs:
- 8% (n = 12)

Herbaceous:
- 77% (n = 117)

Climbers/Vines:
- 4% (n = 6)

Fire Response

Resprouters:
- 52% (n = 79)

Obligate seeders:
- 17% (n= 25)

Life form	OS
Herbaceous	21
Shrub	3
Tree	1
Climber/Vine	0
Total (n)	25

Facultative seeders:
- 24% (n = 36)

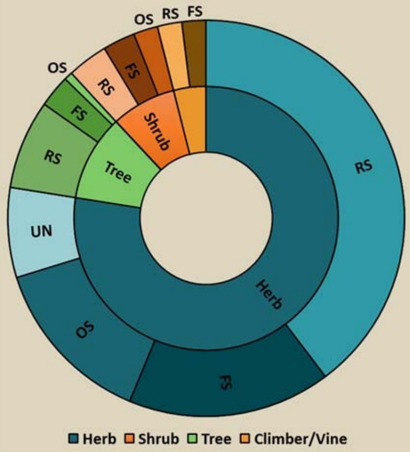
Unknown (UN):
- 7% (n = 11)

Life Form and Fire Response

Resprouters (RS):
- Highest proportion of all life history groups: 69% of trees, 51% of herbaceous species, 50% of climbers/vines and 42% of shrubs

Facultative seeders (FS):
- Higher proportion of climbers/vines (50%) and shrubs (33%)

Obligate seeders (OS):
- Ranged from 6% of trees to 25% of shrubs



3.4.2 Restoration scenarios

As discussed in Section 2.1, there are four approaches to the restoration of fire affected vegetation communities: from protection/natural regeneration through to reconstruction. For the estimates of seed and/or seedlings for Lowland Grassy Woodland, we focus on the combined regeneration/reintroduction approach with an emphasis on obligate seeders.

TABLE 3.4-1. RESTORATION APPROACHES FOR LOWLAND GRASSY WOODLAND

RESTORATION APPROACH	PROTECTION/ NATURAL REGENERATION	FACILITATED NATURAL REGENERATION	COMBINED REGENERATION / REINTRODUCTION	RECONSTRUCTION
GOAL	• **Manage threats**	• **Weed removal (especially transformer weeds) to facilitate regeneration**	• **Weed removal (especially transformer weeds)** • **Facilitate recovery of fire sensitive species**	• **Build buffers around remnants** • **Extend the spatial extent of current patches** • **Improve connectivity between remnants**
DETAILS AND/OR TARGET SPECIES	**Manage threats** • Clearing for rural, agricultural and urban development • Invasion and establishment of transformer weed species • Degradation and competition by rabbits, deer, feral honeybees • Removal of habitat trees • Climate change	**Manage threats** (see Protection) **Weed removal**. Key weeds include: • *Cenchrus clandestinus* (Kikuyu) • *Cirsium vulgare* (Spear Thistle) • *Crataegus monogyna* • *Eragrostis curvula* (African Lovegrass) • *Hypericum perforatum* • *Lycium ferocissimum* (African Boxthorn) • *Nassella trichotoma* • *Rosa rubiginosa* • *Rubus spp.* (Blackberries) • *Solanum spp.* (Nightshades) • *Sporobolus africanus* • *Trifolium repens* (Clover)	**Weed removal** (see Facilitated regeneration) **Reintroduction**: • Site assessments are required to evaluate and quantify missing species and/or functional groups • Fire sensitive species are more likely to be affected by inappropriate fire regimes • Obligate seeders are listed in Table 3.4-2. • Due to the extent of impact, fire affected taxa may require management intervention in terms of seed and/or seedling addition (see Table 3.4-2).	• Requires broad seed inputs • Conservation planning can identify where in the landscape these are positioned to maximise benefits to biodiversity, genetic connectivity and as protection from future fire events

3.4.3 Broad estimates of seed needs

3.4.3.1 Combined regeneration/reintroduction

Estimates of seedling requirements for herbaceous reintroduction post-fire

For Lowland Grassy Woodland, herbaceous species make up the highest proportion of the community (77%, n = 117/151), with 21 of the 117 herbaceous species (17.95%) classified as obligate seeders (see **Figure 3.4-1**). This suggests that ~18% of the herbaceous species may be fire sensitive.

- If 10%[1] (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 17.95% = 0.1795) require reintroduction, and the full reconstruction rate is 410,000 seedlings ha^{-1} (FullRecon, see **Table 3.1-3)**, then approximately 7,359 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.1795 \times 0.1] \times 410000$$

$$N = 0.01795 \times 410000$$

$$N = 7359\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 17.95% = 0.1795) require reintroduction, and the full reconstruction rate is 410,000 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 73,590 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.1795 \times 1.0] \times 410000$$

$$N = 0.1795 \times 410000$$

$$N = 73590\ seedlings\ ha^{-1}$$

This provides a range of 7,359–73,590 herbaceous seedlings ha^{-1}

Estimates of seedling requirements for shrub reintroduction post-fire

Shrubs constitute a smaller percentage of the community (8%), with three of the 12 (25%) shrub species classified as obligate seeders (see **Figure 3.4-1**). This suggests that ~25% of the shrub strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 25% = 0.25) require reintroduction, and the full reconstruction rate is 400 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 10 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.25 \times 0.1] \times 400$$

$$N = 0.025 \times 400$$

$$N = 10 \; seedlings \; ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 25% = 0.25) require reintroduction, and the full reconstruction rate is 400 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 100 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.25 \times 1.0] \times 400$$

$$N = 0.25 \times 400$$

$$N = 100 \; seedlings \; ha^{-1}$$

This provides a range of 10–100 shrub seedlings ha^{-1}

Estimates of seedling requirements for tree reintroduction post-fire

Trees constitute a small proportion of the community (11%, n = 16/151), with 1 of the 16 tree species (6.25%) classified as obligate seeders (see **Figure 3.4-1**). This suggests that ~6% of the tree strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 6.25% = 0.0625) require reintroduction, and the full reconstruction rate is 40 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 0.25 tree seedlings would be required ha^{-1} (1 tree seedling per 4 hectares)(see general equation in Section 2.2.2 and specific example below).

$$N = [0.0625 \times 0.1] \times 40$$

$$N = 0.00625 \times 40$$

$$N = 0.25 \; seedlings \; ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 6.25% = 0.0625) require reintroduction, and the full reconstruction rate is 40 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 3 tree seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.0625 \times 1.0] \times 40$$

$$N = 0.0625 \times 40$$

$$N = 2.5 \; seedlings \; ha^{-1}$$

This provides a range of 0–3 tree seedlings ha^{-1}

As discussed in Section 2.2.1, we also strongly advocate for a staged approach to reintroduction, where facilitated regeneration is applied first as a means of testing natural regenerative capacity and this is particularly relevant for Grassy Woodlands. If there are still non-regenerating species (after adequate time, rainfall and surveys in the right season) then reintroduction is considered.

Adequate time for this process is essential given that native species may take longer timeframes to germinate or have different post-fire establishment trajectories compared to weedy species.

Examining and comparing different establishment methods for Grassy Woodlands is beyond the scope of this report; however, it is important to recognise that regeneration across a site is likely to be spatially variable and that reintroduction nuclei (patches) may provide a means of targeted seed and/or plant addition.

Species also vary in their seed size, viability, germinability and dominance/abundance within a site. It is therefore essential that — after site assessment — each species is considered individually, and the actual amount of seed required calculated using available data on required densities as well as seed quality and quantity.

Obligate seeder shrubs and trees occur within the fire affected species (see **Table 3.4-2)**. However, given their low abundance and restricted distribution within this community, there is currently insufficient information to provide even general estimates on the seed and/or seedling requirements to assist post-fire recovery. We therefore highly recommend targeted field surveys for these species in priority areas.

TABLE 3.4-2. A LIST OF THE FIRE SENSITIVE SPECIES (OBLIGATE SEEDERS (OS)) FROM THE LOWLAND GRASSY WOODLAND IN THE SOUTH EAST CORNER BIOREGION TEC SPECIES LIST AND THE FIRE AFFECTED SPECIES WITHIN THE TEC 'LIKELY TO OCCUR' BOUNDARY. LIFE FORM: HERBACEOUS (H), SHRUB (S), TREE (T). SEED STORAGE: SOIL (S), TRANSIENT (T), CANOPY (C), UNKNOWN (UN).

IDENTIFICATION SOURCE	SCIENTIFIC NAME	LIFE FORM	FIRE RESPONSE	SEED STORAGE	MANAGEMENT INTERVENTION (EXPERT PANEL)
TEC species list	*Acacia mearnsii*	T	OS	S	
TEC species list	*Ajuga australis*	H	OS[1]	UN	
TEC species list	*Calotis lappulacea*	H	OS[2]	UN	
TEC species list	*Cassinia aculeata*	S	OS	S	
TEC species list	*Chenopodium carinatum*	H	OS	UN	
TEC species list	*Cullen microcephalum*	H	OS	S	
TEC species list	*Cynoglossum australe*	H	OS[3]	UN	
TEC species list	*Dodonaea viscosa subsp. angustifolia*	S	OS[4]	UN	
TEC species list	*Dysphania pumilio*	H	OS	UN	
TEC species list	*Einadia hastata*	H	OS	UN	
TEC species list	*Einadia nutans*	H	OS	UN	
TEC species list	*Einadia trigonos*	H	OS	S	
TEC species list	*Galium leiocarpum*	H	OS	UN	
TEC species list	*Lagenophora stipitata*	H	OS	UN	
TEC species list	*Lobelia purpurascens*	H	OS	UN	
TEC species list	*Ozothamnus argophyllus*	S	OS	T	
TEC species list	*Polygala japonica*	H	OS	T	
TEC species list	*Ranunculus lappaceus*	H	OS	T	
TEC species list	*Senecio hispidulus var. hispidulus*	H	OS	UN	
TEC species list	*Senecio quadridentatus*	H	OS	T	
TEC species list	*Sigesbeckia orientalis subsp. orientalis*	H	OS	S	
TEC species list	*Solanum prinophyllum*	H	OS	UN	
TEC species list	*Solanum pungetium*	H	OS	UN	
TEC species list	*Sorghum leiocladum*	H	OS1	UN	
Fire affected species	*Acacia trachyphloia*	S	OS	UN	Yes
Fire affected species	*Boronia subulifolia*	S	OS	UN	Yes
Fire affected species	*Eucalyptus fraxinoides*	T	OS	C	Yes
Fire affected species	*Zieria caducibracteata*	S/T	OS	UN	Yes

[1] Originally classified as OS by Bradstock (2020)[27] but RS in Clarke *et al.* (2000)[28]

[2] Originally classified as OS by Hunter (2010)[29] but resprouting observed Greening Australia (2017)[30]

[3] Originally classifies as OS by Muir et al. (2015)[31] but RS in Clarke *et al.* (2000)[28]

[4] Originally classified as OS by Hunter (2010)[29] but RS in Clarke *et al.* (2000)[28]

3.5 Silurian Limestone Pomaderris Shrubland (SLPS)

3.5.1 Description

The Silurian Limestone Pomaderris Shrubland of the South East Corners and Australian Alps Bioregions (SLPS) only occurs in eastern Victoria's Marble Gully Nature Conservation Reserve (managed by Parks Victoria).[32]

Characteristic features of the one known site include mean annual rainfall of approximately 645mm/year at elevations of 600m above sea level. Soils are skeletal from Silurian limestone and marble with prominent outcrops on north-facing and steep (40–60°) slopes.[32]

The main dominating species is Limestone Pomaderris (*Pomaderris oraria* subsp. *calcicole*) which is a rare shrub. Drooping Sheoak (*Allocasuarina verticillate*) and Silver Bundy (*Eucalyptus nortonii*) are also found throughout the canopy layer. The ground layer commonly consists of Winged Everlasting (*Ozothamnus adnatus*) and Kangaroo Grass (*Themeda triandra*). Two distinct sub-communities are further described in the national recovery plan.[32]

The majority of species are obligate seeders (35%, see **Figure 3.5-1**) with many facultative seeders (31%) and some resprouters (27%). Herbaceous species make up over half of the flora species (62%) with shrubs making up just less than a third of the species (31%) and trees make up the remaining 8%. The proportion of obligate seeders is highest in the shrubs (50%) and herbaceous (31%) life form groups (**Figure 3.5-1**).

FIGURE 3.5-1. A SUMMARY OF THE COMMUNITY COMPOSITION, LIFE FORM AND FIRE RESPONSE OF SPECIES FROM THE SILURIAN LIMESTONE POMADERRIS SHRUBLAND. RS = REPROUTERS, OS = OBLIGATE SEEDERS, FS = FACULTATIVE SEEDERS, UN = UNKNOWN.

Community Characteristics

Number of species:
- 26 [24 genera]

Trees:
- 8% (n = 2)

Shrubs:
- 31% (n = 8)

Herbaceous:
- 62% (n = 16)

Fire Response

Resprouters:
- 27% (n = 7)

Obligate seeders:
- 35% (n= 9)

Life form	OS
Herbaceous	5
Shrub	4
Tree	0
Total (n)	19

Facultative seeders:
- 31% (n = 8)

Unknown:
- 8% (n = 2)

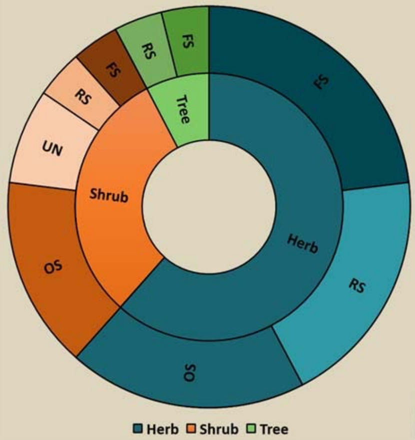
Life Form and Fire Response

Resprouters (RS):
- Ranged from 12% of shrubs to 31% of Herbaceous species and 50% of trees

Facultative seeders (FS):
- Higher proportion of herbaceous species (38%) and trees (50%)

Obligate seeders (OS):
- Higher proportion of herbaceous species (31%) and shrubs (50%)

Unknown fire response (UN):
- Shrubs had the highest proportion of unknown fire responses (25%)



3.5.2 Restoration scenarios

As discussed in Section 2.1, there are four approaches to the restoration of fire affected vegetation communities: from protection/natural regeneration through to reconstruction. For the estimates of seed and/or seedlings for Silurian Limestone Pomaderris Shrubland, we focus on the combined regeneration/reintroduction approach with an emphasis on obligate seeders.

TABLE 3.5-1. RESTORATION APPROACHES OF SILURIAN LIMESTONE POMADERRIS SHRUBLAND

RESTORATION APPROACH	PROTECTION/ NATURAL REGENERATION	FACILITATED NATURAL REGENERATION	COMBINED REGENERATION / REINTRODUCTION	RECONSTRUCTION
GOAL	• **Manage threats**	• **Weed removal Facilitate regeneration**	• **Weed removal** • **Facilitate recovery of fire sensitive species**	• **Build buffers around existing patches** • **Extend the spatial extent of current patches**
DETAILS AND/OR TARGET SPECIES	**Manage threats** • Grazing (domestic cattle and rabbits) • Invasion and establishment of weed species • Increased fire frequency • Potential disturbance from mining and recreational use	**Manage threats** (see Protection) **Weed removal**. Key weeds include: • *Rubus fruiticosus* (Blackberry) • *Anagallis arvensis* (Pimpernel) • *Cardamine hirsute* (Common Bittercress) • *Catapodium rigidum* (Rigid Fescue) • *Centaurium erythaea* (Common Centaury) • *Marrubium vulgare* (Horehound) • *Petrorhagia velutina* (Velvet Pink) • *Rosa rubiginosa* (Sweet Briar)	**Weed removal** (see Facilitated regeneration) **Reintroduction**: • Site assessments are required to evaluate and quantify missing species and/or functional groups • Fire sensitive species (obligate seeders and to a lesser extent facultative seeders) are more likely to be affected by inappropriate fire regimes • Obligate seeders are listed in Table 3.5-2. • Due to the extent of impact, fire affected taxa may require management intervention in terms of seed and/or seedling addition (see Table 3.5-2).	• Requires broad seed inputs • Given the small spatial extent of this community, conservation planning can identify where in the surrounding landscape these established populations are positioned to: (i) maximise biodiversity benefits, and (ii) provide protection from future fire events

3.5.3 Broad estimates of seed needs

3.5.3.1 Combined regeneration/reintroduction

Estimates of seedling requirements for herbaceous reintroduction post-fire

For Silurian Limestone Pomaderris Shrubland, herbaceous species make up the highest proportion of the community (61%, n = 16/26), with 5 of the 16 herbaceous species (31.25%) classified as obligate seeders (see **Figure 3.5-1**). This suggests that ~31% of the herbaceous strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 31.25% = 0.3125) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 139 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.3125 \times 0.1] \times 4444$$

$$N = 0.03125 \times 4444$$

$$N = 139\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 31% = 0.31) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 1,389 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.3125 \times 1.0] \times 4444$$

$$N = 0.3125 \times 4444$$

$$N = 1389\ seedlings\ ha^{-1}$$

This provides a range of 139–1,389 herbaceous seedlings ha^{-1}

Estimates of seedling requirements for shrub reintroduction post-fire

Shrubs constitute a smaller proportion of the community (31%, n = 8/26), with 4 of the 8 shrub species (50%) classified as obligate seeders (see **Figure 3.5-1**). This suggests that ~21% of the shrub strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 50% = 0.5) require reintroduction, and the full reconstruction rate is 2,500 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 125 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.5 \times 0.1] \times 2500$$

$$N = 0.05 \times 2500$$

$$N = 125\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 50% = 0.5) require reintroduction, and the full reconstruction rate is 2,500 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 1,250 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.5 \times 1.0] \times 2500$$

$$N = 0.5 \times 2500$$

$$N = 1250\ seedlings\ ha^{-1}$$

This provides a range of 125–1,250 shrub seedlings ha^{-1}

Table 3.5-2. A list of the fire sensitive species (obligate seeders (OS)) from the Silurian Limestone Pomaderris Shrubland of the South East Corner and Australian Alp Bioregion TEC species list and the fire affected species within the TEC 'likely to occur' boundary. Life form: Herbaceous (H), Shrub (S). Seed storage: Soil (S), Transient (T), Unknown (UN).

IDENTIFICATION SOURCE	SCIENTIFIC NAME	LIFE FORM	FIRE RESPONSE	SEED STORAGE
TEC species list	*Asplenium trichomanes subsp. quadrivalens*	H	OS	UN
TEC species list	*Irenepharsus magicus*	H	OS	UN
TEC species list	*Isoetopsis graminifolia*	H	OS	UN
TEC species list	*Pimelea flava*	S	OS	UN
TEC species list	*Pimelea flava subsp. dichotoma*	S	OS	UN
TEC species list	*Pimelea pauciflora*	S	OS	S
TEC species list	*Pomaderris oraria subsp. calcicola*	S	OS	S
TEC species list	*Senecio quadridentatus*	H	OS	T
TEC species list	*Vittadinia tenuissima*	H	OS	UN

3.6 Eastern Stirling Range Montane Heath and Thicket (ESRMHT)

3.6.1 Description

The Eastern Stirling Range Montane Heath and Thicket (ESRMHT) is restricted to the eastern regions of the Stirling Ranges in Western Australia.[33] It typically occurs at high altitudes (750–1,080m above sea level)[33] across 10 mountain summits totalling 334ha.[34] There are eleven threatened flora species including Giant Andersonia (*Andersonia axilliflora*), Brown's Banksia (*Banksia brownii*) and Stirling Range Dryandra (*Dryandra montana*). *Andersonia axilliflora* is also a key indicator species for the TEC's distribution, has been classed as Critically Endangered (CR) and is endemic to the area. Other characteristic species include *Andersonia echinocephala,* Dark Beaufortia (*Beauforia anisandra*) and Mountain Kunzea (*Kunzea montana*).

The majority of species are obligate seeders (53%, see **Figure 3.6-1**) with very few resprouters (6%) and facultative seeders (3%). The high proportion of obligate seeders means that this community would be generally classified as fire sensitive and vulnerable to inappropriate fire frequencies (i.e. fires that are too frequent). In addition, being a montane community with skeletal organic soils means that it has a shorter growing season and generally lower productivity. This can result in longer primary juvenile periods for obligate seeders to reach reproductive maturity, and lead to the need for greater fire-free intervals to replenish the seed bank.[35] This community is also under threat by *Phytophthora* dieback, with synergistic threats of frequent fire and disease, especially for susceptible Proteaceous obligate seeders.[35] Shrubs make up most flora species (66%) with the remaining species being herbaceous (34%). There are no tree species in the ESRMHT. Obligate seeders are a large proportion of shrubs (65%) and herbaceous species (30%) (**Figure 3.6-1**).

Figure 3.6-1. A summary of the community composition, life form and fire response of species from the Eastern Stirling Ranges Montane Heath and Thicket. RS = Resprouters, OS = Obligate seeders, FS = Facultative seeders, UN = Unknown.

Community Characteristics

Number of species:
- 79 [55 genera]

Shrubs:
- 66% (n = 52)

Herbaceous:
- 34% (n = 27)

Fire Response

Resprouters:
- 6% (n = 5)

Obligate seeders:
- 53% (n= 42)

Life form	OS
Herbaceous	8
Shrub	34
Total (n)	42

Facultative seeders:
- 3% (n = 2)

Unknown:
- 38% (n = 30)

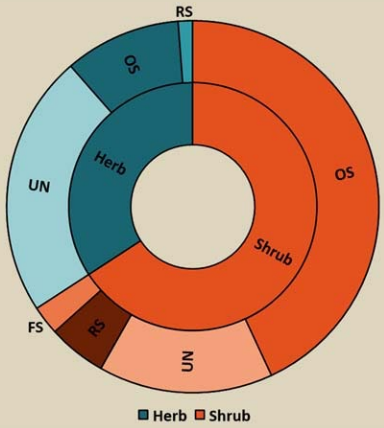
Life Form and Fire Response

Resprouters (RS):
- Ranged from 4% of herbaceous species to 8% of shrubs

Facultative seeders (FS):
- Low proportion of shrubs (4%)

Obligate seeders (OS):
- Higher proportion of shrubs (65%)

For each life form:
- Higher unknown (UN) fire responses in herbaceous species (67%) compared to shrubs (23%)



3.6.2 Restoration scenarios

As discussed in Section 2.1, there are four approaches to the restoration of fire affected vegetation communities: from protection/natural regeneration through to reconstruction. For the estimates of seedling requirements for the Eastern Stirling Range Montane Heath and Thicket, we focus on the combined regeneration/reintroduction approach with an emphasis on obligate seeders.

TABLE 3.6-1. RESTORATION APPROACHES OF EASTERN STIRLING RANGE MONTANE HEATH AND THICKET

RESTORATION APPROACH	PROTECTION/ NATURAL REGENERATION	FACILITATED NATURAL REGENERATION	COMBINED REGENERATION / REINTRODUCTION	RECONSTRUCTION
GOAL	• **Manage threats**	• **Weed removal to facilitate regeneration**	• **Weed removal** • **Facilitate recovery of fire sensitive species**	• **Build insurance populations in *Phytophthora* free areas**
DETAILS AND/OR TARGET SPECIES	**Manage threats** • Phytophthora dieback (*Phytophthora cinnamomic*) infestation • Inappropriate fire regimes • Grazing • Recreational activity disturbances e.g., litter, track braiding, erosion • Climate change	**Manage threats** (see Protection) **Weed removal**. Key weeds include: • *Aira spp.* • *Avena barbata* (Bearded Oat) • *Briza minor* (Shivery Grass) • *Bromus diandrus* • *Centaurium spp.* • *Ehrharta calycina* (Perennial Veldt Grass) • *Eragrostis curvula* (African Lovegrass) • *Moraea setifolia* • *Phalaris minor* (Lesser Canary Grass) • *Romulea rosea* (Guilford Grass) • *Trifolium spp.*	**Weed removal** (see facilitated regeneration) **Reintroduction**: • Site assessments are required to evaluate and quantify missing species and/or functional groups • Fire sensitive species obligate seeders are more likely to be affected by inappropriate fire regimes • Obligate seeders are listed in Table 3.6-2. • Obligate seeders susceptible to Phytophthora dieback are also identified	• Requires broad seed inputs • Conservation planning can identify where in the landscape these are positioned to reduce the risk of *Phytophthora*, maximise genetic connectivity and as protection from future fire events

3.6.3 Broad estimates of seed needs

3.6.3.1 Combined regeneration/reintroduction

For the Eastern Stirling Range Montane Heath and Thicket community, restoration is also complicated by *Phytophthora* dieback. Here, restoration of individuals of susceptible species is not generally undertaken in infected areas and restoration protocols in relation to disease management have been established by the Department of Biodiversity, Conservation and Attractions (Western Australia).

Estimates of seedling requirements for shrub reintroduction post-fire

For montane heath and thicket, trees are absent, and shrubs make up the highest proportion of the community (66%, n = 52/79), with most shrubs (34 of the 52 species (65.38%) classified as obligate seeders (see **Figure 3.6-1**). This suggests that ~65% of the shrub strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 65.38% = 0.6538) require reintroduction, and the full reconstruction rate is 3,086 seedlings ha^{-1} (FullRecon, see **Table 3.1-3)**, then approximately 202 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.6538 \times 0.1] \times 3086$$

$$N = 0.06538 \times 3086$$

$$N = 202\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 65.38% = 0.6538) require reintroduction, and the full reconstruction rate is 3,086 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 2,018 shrub seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.6538 \times 1.0] \times 3086$$

$$N = 0.6538 \times 3086$$

$$N = 2018\ seedlings\ ha^{-1}$$

This provides a range of 202–2,018 shrub seedlings ha^{-1}

Estimates of seedling requirements for herbaceous reintroduction post-fire

Herbaceous species constitute a smaller proportion of the community (34%), with eight of the 27 (29.63%) herbaceous species classified as obligate seeders (see **Figure 3.6-1**). This suggests that ~30% of the herbaceous strata may be fire sensitive.

- If 10% (%Reintro = 10% = 0.1) of the fire sensitive species (%FireSen = 29.63% = 0.2963) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 132 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.2963 \times 0.1] \times 4444$$

$$N = 0.02963 \times 4444$$

$$N = 132\ seedlings\ ha^{-1}$$

- If 100% (%Reintro = 100% = 1.0) of the fire sensitive species (%FireSen = 29.63% = 0.2963) require reintroduction, and the full reconstruction rate is 4,444 seedlings ha^{-1} (FullRecon, see **Table 3.1-3**), then approximately 1,317 herbaceous seedlings would be required ha^{-1} (see general equation in Section 2.2.2 and specific example below).

$$N = [0.2963 \times 1.0] \times 4444$$

$$N = 0.2963 \times 4444$$

$$N = 1317\ seedlings\ ha^{-1}$$

This provides a range of 132–1,317 herbaceous seedlings ha^{-1}

Table 3.6-2. A list of the fire sensitive species (obligate seeders (OS)) from the Eastern Stirling Range Montane Heath and Thicket TEC species list and the fire affected species within the TEC 'likely to occur' boundary. Life form: Herbaceous (H), Shrub (S). Seed storage: Soil (S), Canopy (C), Unknown (UN).

IDENTIFICATION SOURCE	SCIENTIFIC NAME	LIFE FORM	FIRE RESPONSE	SEED STORAGE	SUSCEPTIBLE TO *PHYTOPHTHORA*
TEC species list	*Acacia drummondii subsp. elegans*	S	OS	S	
TEC species list	*Actinotus rhomboideus*	S	OS	S	
TEC species list	*Adenanthos filifolius*	S	OS	S	Y
TEC species list	*Andersonia axilliflora*	S	OS	S	Y
TEC species list	*Andersonia echinocephala*	S	OS	S	Y
TEC species list	*Aotus genistoides*	S	OS	S	
TEC species list	*Banksia brownii*	S	OS	C	Y
TEC species list	*Banksia concinna*	S	OS	C	Y
TEC species list	*Banksia formosa*	S	OS	C	Y
TEC species list	*Banksia montana*	S	OS	C	Y
TEC species list	*Banksia solandri*	S	OS	C	Y
TEC species list	*Banksia oreophila*	S	OS	C	Y
TEC species list	*Beaufortia anisandra*	S	OS	C	Y
TEC species list	*Billardiera drummondii*	H	OS	S	
TEC species list	*Cassytha glabella*	H	OS	UN	
TEC species list	*Darwinia collina*	S	OS	S	Y
TEC species list	*Darwinia nubigena (sp. Stirling Range)*	S	OS	UN	Y
TEC species list	*Darwinia squarrosa*	S	OS	UN	Y
TEC species list	*Deyeuxia drummondii*	H	OS	S	
TEC species list	*Gastrolobium leakeanum*	S	OS	S	Y
TEC species list	*Hibbertia argentea*	S	OS	S	Y
TEC species list	*Isopogon latifolius*	S	OS	C	Y
TEC species list	*Kunzea montana*	S	OS	S	Y
TEC species list	*Lambertia fairallii*	S	OS	C	Y
TEC species list	*Lambertia uniflora*	S	OS	C	Y
TEC species list	*Latrobea colophona*	S	OS	S	Y
TEC species list	*Leptomeria squarrulosa*	S	OS	C	
TEC species list	*Leucopogon atherolepis*	S	OS	S	Y
TEC species list	*Leucopogon gnaphalioides*	S	OS	S	Y
TEC species list	*Microcorys sp. Stirling Range*	S	OS	S	
TEC species list	*Muiriantha hassellii*	S	OS	S	
TEC species list	*Persoonia micranthera*	S	OS	S	Y

IDENTIFICATION SOURCE	SCIENTIFIC NAME	LIFE FORM	FIRE RESPONSE	SEED STORAGE	SUSCEPTIBLE TO *PHYTOPHTHORA*
TEC species list	*Platysace sp. Stirling Range*	S	OS	S	Y
TEC species list	*Sphenotoma drummondii*	S	OS	S	Y
TEC species list	*Sphenotoma sp. Stirling Range*	S	OS	S	Y
TEC species list	*Spyridium montanum*	S	OS	S	
TEC species list	*Stylidium bellum*	H	OS	S	
TEC species list	*Stylidium keigheryi*	H	OS	S	
TEC species list	*Stylidium rosulatum*	H	OS	S	
TEC species list	*Stylidium sp. Bluff Knoll*	H	OS	S	
TEC species list	*Taxandria floribunda*	S	OS	C	
TEC species list	*Xyris exilis*	H	OS	S	

4 CONCLUSIONS

For fire affected habitats, the degree of post-fire management intervention required will depend on the inherent regenerative capacity of the community (based on species composition and traits) and how this interacts with habitat condition (pre- and post-fire), fire severity and landscape context.

Using restoration scenarios for five TECs that represent different vegetation types, seedling addition rates (seedlings required per hectare (h^{-1})) varied between communities as a function of species composition (proportion of obligate seeders, facultative seeders and resprouters) and dominant life form (trees, shrubs or herbaceous).

These general seed estimates — that ranged from reintroducing 10% of the fire sensitive species through to reintroduction of all fire sensitive species — can be used as a lower and upper bound for potential seed requirements for bushfire recovery.

> These broad values can be used by the native seed industry to assess current seed availability and collection capacity, plan for seasonal seed collection, develop capacity for biobanking in seed banks, consider climate adjusted approaches to seed collection and maximise the likelihood of restoration success through adequate species and genetic diversity.

For each TEC, site assessments of the priority areas (1 and 2) identified through the GIS models outlined in *Bushfire impacts — A national model for assessing local landscape restoration priorities* could be used to evaluate areas most likely to need intervention. Once these areas have been assessed and it is established that any fire sensitive species (obligate seeders) or other functional groups are missing, then facilitated regeneration could be applied to test regeneration capacity. If these fire sensitive species (or other groups) are still not regenerating, then an assessment of the potential number of seedlings (and associated seed) required to support recovery towards a particular reference community could be undertaken.

This could be done by first obtaining knowledge of the seed biology of these species (e.g. seed viability and germinability). Secondly, this information on seed biology would need to be combined with the estimated seedling addition rates and local knowledge of the vegetation community to enable the required seedling inputs to be calculated.

Vegetation communities in Australia have shown incredible resilience to the Black Summer fires — even communities such as rainforests that have not evolved with frequent fire (see case studies in *Bushfire impacts — A national model for assessing local landscape restoration priorities*, Section 4).

Consequently, even though it is important to consider various scenarios for post-fire reintroduction, it is possible that with facilitated regeneration most areas will not require seed, seedling or propagule addition. It is also likely that given enough time, many communities will re-establish and maintain a trajectory towards recovery — if ongoing threats are managed. However, in some communities (e.g. rainforest) with relatively slow post-disturbance successional processes, targeted reintroduction can play a role in speeding up community recovery and counteracting ongoing threats.

This is where habitat condition assessments, as well as spatial analysis, can play a role in identifying areas most likely to need management intervention.

5 RECOMMENDATIONS

There are several recommendations for the ten-year Strategy[1] that will utilise and extend the information presented in this report. These relate to both the seedling estimates for each community type and their specific application to the post-fire restoration of the TEC examples.

1. **A coordinated program of site assessments is required to ground truth estimates of seed and/or seedling requirements for different community types.**

This will enable an evaluation of whether fire sensitive species in these groups are regenerating post-fire and if a combined regeneration/reintroduction approach is appropriate and/or effective. A coordinated approach with standardized methods will enable replication and comparison across community types (such as within the Monitoring, Evaluation and Research (MER) Network).

2. **Build capacity across the sector (through access to training, infrastructure and funding) to undertake facilitated regeneration approaches alongside any seed, seedling or propagule addition.**

Native species establishment is unlikely to be achieved without effective weed management.

3. **Further research into the seed biology of priority species in fire affected areas is required to enable more accurate estimates of the seed needs to facilitate restoration potential.**

This also links to the need for more research into Seed Production Areas (SPAs) as a means of increasing the availability of priority species. SPA development and biobanking for fire sensitive species will require partnerships between government, academics, NGOs, land managers, community groups and practitioners.

4. **Generate and establish an open access centralised database of seed and seedling requirements for different community types to develop collective knowledge in the native seed sector.**

5. **An assessment of species composition within each TEC is required, especially post-fire.**

This will provide information on recovery trajectories and enable an assessment of current seed demand as well as help identify populations that may be used as collections in the future (e.g. for biobanking and/or SPA development).

[1] This report contributes to the evidence base for a ten-year strategy to guide the native seed and landscape sector. The document, which is untitled until endorsement in September 2021, is referred to as the Strategy in all Project Phoenix publications.

6. More information on species distribution, post-fire recovery and seed biology is required for the fire affected species within the fire scar of these TECs.

This information will enable accurate estimates of the management interventions required for these species and provide a means of establishing conservation priorities.

7. Landscape level conservation planning is required to assist in estimating the seed required for reconstruction to increase landscape resilience of fire affected TECs.

This should consider how restoration may counteract current threats and processes (e.g. by increasing connectivity, gene flow or spatial extent) as well as provide insurance against future threats (e.g. increased fire frequency and intensity, climate change).

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