Chapter S4 Ecological theory

IN FRAGMENTED LANDSCAPES, MISTLETOES START RAINFORESTS!

Princes Highway at the Tuross turnoff, New South Wales. Ecological processes are all around us: it just takes a different way of looking at the world to a see and understand them so you can apply these to the ecological restoration process. Here, Black Wattle *Acacia mearnsii* (alone) offers little to a passing fruit-eating bird, but with the advent of mistletoe (in this case Variable Mistletoe *Amyema congener*), there is a reason to stop, feed and drop the seed of a previous meal of rainforest fruits. This has ***transformed*** this single tree, into an emerging rainforest site, with species already present including: Sweet Pittosporum *P. undulatum* (pictured), Poison Peach *Trema tomentosa* and Wombat Berry *Eustrephus latifolius*. See Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes.

Introduction

There are several ecological theories and techniques that are relevant to rainforest restoration. Although you do not need to know these in detail, a brief outline of the key theories will help you understand the "how and why" of what we suggest for rainforest restoration in the Manual. Before proceeding further, you will find it useful to take in a quick overview of rainforest ecology before you begin this section. So read Chapter 2: Rainforest ecology: a crash course: How fire works and what landscapes can do to modify its behaviour to provide fire refuges for rainforests and the relevant fire-related sections of Chapter 7: Managing disturbance because, although fire is not discussed in detail here, it does mediate the distribution of rainforest in the landscape (Bowman 2000) and much of its ecology.

Here is some jargon relating to rainforest that you will come across and the key theories they represent:

- Pioneer species (the first on the scene)
- Secondary species (next in line)
- *Primary species* (most people's idea of 'real rainforest', *scrub*, *brush* or *jungle*)
- Succession and natural regeneration (free plants brought to you by natures ecological processes)
- Niches (who lives where and why)
- *Ecosystem resilience* (it is not all hopeless: you can make a difference)
- Remnants (what are left for you to work on).

Ecological principles

A lot of the successful rainforest restoration done to date has been through the innate (and considerable) ecological abilities and observation of the current practitioners and their predecessors. Such restoration efforts have been started from ecological first principles.

Definitions

This next section provides the definitions for these vital ecological principles that you can then all apply to your restoration sites. Understand these, and you will have gained a fundamental insight into the ecology of your rainforest and what you are actually trying to do when you attempt to restore them. These definitions provide you with the tool kit for doing restoration work as well as introducing you to the means required to troubleshoot any problems that may arise along the way.

Pioneer species (the first to arrive and start the succession race)

Pioneer species as the name suggests, are the first on the scene to germinate and colonise the site after disturbance. They are the first in the ***primary succession*** race, which if the site is left undisturbed, will in time finish with the regeneration of a mature rainforest composed of its primary species. The race they run and the role they play is vital, but relatively short in duration.

Pioneer species have the following features:

- They require catastrophic disturbance (fire, soil disturbance, flood, etc.) to germinate and establish en masse (whereby the disturbance switches the site from ***full shade*** beneath the intact canopy into full sun following the canopy's disruption or destruction)
- The pioneer species common in rainforest that come after disturbance are highly combustible and have very short ignition times (1.6-11 seconds; Additional Reading: Ignition times)
- They are often narrow-leaved [when compared with other members of their genus that occur in different successional categories: e.g. Snowy Daisy-bush *Olearia lirata* (a pioneer) compared with Musk Daisy-bush *O. argophylla* (a late secondary species)]
- Such species are sun-dependent
- They are very frost hardy species (for the usual frost regimes of their region)
- All are exposure tolerant: particularly to extremes of temperature >43-46^{o}C [for the lowlands of the warm temperate climate zone in south-eastern Australia (Additional Reading: Extreme weather: Figures AR116 and AR117)]
- Most have light-permeable crowns that cast light shade (*EV* readings of 13-15 are usual)
- All are fast growing
- Each is short-lived (generally less than 10-15 years) with some, such as the annuals and biennials, having germinated, flowered and committed their seed to the soil seed bank by the third year (Coulton *et. al*. 2009)
- All die out when the site becomes fully shaded.

Pioneer species have the following establishment requirements:

- They colonise sunny gaps in rainforest (EV readings of 16-17)
- They colonise gaps with transitory shade (with long periods of sun from midday to afternoon).

Their seeds are durable and long-lived, often being stored in the soil seed bank for decades, or even centuries, to await the next disturbance event that will see sunlight once more reach the ground and stimulate them to regenerate en masse. Another important feature is that they have a short leaf-life and rapidly form leaf-litter: a significant ecological milestone for young rainforests. Their exposure tolerance provides shelter to less exposure-hardy species that will follow.

Examples include: Coast Wattle *Acacia longifolia* ssp. *sophorae*, Sallow Wattle *A. longifolia* ssp. *longifolia*, Tree Everlasting *Ozothamnus ferrugineus* and Fireweed Groundsel *Senecio linearifolius*.

Uses: Planted first, they are the nursery crops that shelter the more sensitive secondary and primary species from the extreme elements of full exposure: wind, sun, drought, fire and frost.

Secondary species (the vital link between the starters and the finishers)

As their name suggests they the second to come on to the scene and establish. They most often do so as a result of large-scale disturbance in the presence of the pioneer species that supply the shelter from the elements that they need to establish. The secondary species are the middle distance runners of the succession race. These species have a middle of the road life-expectancy: living longer than pioneer species, but generally shorter than the primary species in the same life form category.

Secondary species have the following features:

- Although these species do not necessarily require catastrophic or broad scale disturbance for establishment, they do develop in the shelter of pioneer species that regenerated following such disturbance events
- The secondary species common in rainforest that come up after disturbance are moderately combustible and have longer ignition times than pioneers (11-21 seconds and some species do not ignite; Additional Reading: Ignition times)
- They are sun tolerant; but are importantly are also tolerant of light shade (EV 13-15)
- They are generally broad-leaved in their own right e.g. Musk Daisy-bush *Olearia argophylla* (or are broad-leaved relative to other members of their genus e.g. Sword Tussock-grass *Poa ensformis* versus Grey Tussock-grass *Poa sieberiana*) reflecting their shadier growth niches that are influenced by other pioneer and secondary species growing over them or nearby
- Relatively frost hardy: more so than primary species but less so than pioneer species (especially when young) in the context of the frost regime for their region;
- Some exposure sensitivity relative to pioneer species, but not as shelter-dependent as primary species
- Some appear tolerant of extreme temperature: particularly to extremes of temperature >43-46^{o}C for the lowlands of the warm temperate climate zone in south-eastern Australia (Additional Reading: Extreme weather: Figures AR116 and AR117)
- They have only moderately light-permeable crowns, casting moderate to light shade (EV of 10-15)
- They are moderately fast growing
- They have moderate life spans of several to many decades (rarely exceeding a century)
- *Early secondary species* die out when shaded (because of their smaller stature)
- Late secondary species are generally trees and vines that can avoid shading by growing into the light.

Secondary species have the following establishment requirements:

- Species in this group establish in the shade of pioneer species (light shade) or in the lightly to moderately shaded or transitory shade gaps of mature rainforest
- It is postulated that this shadier niche (compared with the bright sunny gaps needed by pioneer species) is in part due to a requirement for cooler soils for establishment
- Some of the longer-lived species are able to subsist as nearly leafless plants beneath the mature rainforest canopy, only to burst back into full leaf when a gap opens above them. Classic examples include: Blanket-leaf *Bedfordia arborescens* and Musk Daisy-bush *Olearia argophylla*.

General characteristics: Their seed has varying longevity, with species such as wattles lasting decades if not centuries, and those that are wind-dispersed, such as Coast Banksia *B. integrifolia*, dying within the year after being shed. Each group employs a different strategy after disturbance: those with long-lived seed await the next disturbance in the soil seed bank; those with short-lived seed rely on having ripe seed on the plant within dispersal distance of the new niche, at the time of the disturbance event required for their establishment. In general, secondary seeders produce abundant seed crops reliably every year (Nicholson and Nicholson 1995) in order to maximise their chances of having their propagules ready for when their establishment niche appears (cf. primary species). Secondary species are believed to have life-expectancies for their leaves that are intermediate between pioneer species and primary species. Secondary species can be further divided into two groups:

- Early secondary species: these species establish in light shade, but, because of their smaller growth habit (shrubs, grasses or ferns) and/or life-expectancies compared with the rest of the surrounding species of the successional stage, they are unable to compete when moderate to deep shade develops as rainforest succession moves towards the climax state (a canopy dominated by the light impermeable crowns of the primary species).

- Late secondary species: These plants are usually long-lived trees or vines that may persist on the site for decades after the initial disturbance event that allowed them to germinate and establish. They accommodate their need for light by being big enough in the case of trees or agile enough if they are vines, to be a part of the canopy.

Examples of early secondary species include: some grasses: Coast Wattle *Acacia longifolia* ssp. *sophorae*, Sword Tussock-grass *Poa ensiformis*, Common Tussock-grass *P. labillardierii*, and ferns such as Downy Ground-fern *Hypolepis glandulifera* and Harsh Ground-fern *H. muelleri* (compare these with primary species in the same life form categories under the definition of pioneer species).

Examples of late secondary species include: Blackwood *A. melanoxylon*, Red Ash *Alphitonia excelsa*, Brush Kurrajong *Commersonia fraseri*, Southern Kurrajong (Blackfellow's Hemp) *C. rossii*, Giant Stinging-tree *Dendrochnide excelsa*, Dubosia *D. myoporoides*, Guioa *G. semiglauca*, Gippsland Hemp Bush *Gynatrix macrophylla*, Pencil Cedar *Polyscias murrayi* and Hazel Pomaderris *Pomaderris aspera.*

Uses: Secondary species are bigger and longer-lived, and so have a role in providing shelter and niches for the establishment of slow growing primary species and the development of the mature rainforest canopy. Many secondary species have extensive lichen and other ***bryophyte*** colonies on their trunks: these are used by many rainforest birds as nesting materials.

Primary species (the race finishers that become the mature rainforest)

Primary or mature phase species are very different to the two previous categories in their establishment requirements and the niches that they create in rainforest. They are the species that will develop into what most people (perhaps even you) think of as rainforest: dark, moist and festooned with ferns and vines. The reality is though that this would be the equivalent of taking only the people 30-40years old and over in our society and saying that is the sum of the human race. Clearly they are not, and ignoring the other earlier 'nursery' stages and their species in rainforest establishment, renewal and persistence would be just as inappropriate when describing rainforest and considering rainforest ecology.

Primary species are the last on the scene and can germinate and establish in the absence of disturbance, even in deep shade. These species are the end point of the race and constitute the mature rainforest. The reality is though that there are few extensive areas composed entirely of primary species alone, because minor disturbances such as tree-fall, canopy death and so on allow the late secondary species into these small gaps. Such gaps also 'release' the primary species' seedlings that have previously established (and exist as small shrubs or saplings beneath the deep shade of the mature rainforest canopy). Their strategy has been sitting there in the deep shade putting on a couple of leaves per branch per year and biding their time and waiting for the gap to appear overhead. These mature phase primary species then have the ability to be able to quickly switch into growth mode and fill these small scale gaps in the rainforest's canopy. Importantly, they also have seedlings that are able both establish and to keep actively growing beneath the crowns of the secondary species because they only cast light to ***moderate shade***. In time, their steady growth and strength allows them to gain in size and strength. By the time that the secondary plant has begun to senesce and nears the end of its life, the young vigorous primary species are ready to assume their role in closing out the canopy. If everything has gone to plan, then by the time that the secondary species die, the canopy is virtually filled by the primary species that established beneath the secondary species.

Primary species have the following features:

- They regenerate and establish in the absence of disturbance.
- The primary species that form the mature rainforest regenerate in the absence of catastrophic disturbance have the longest ignition times compared with pioneers and most secondary species [>12 seconds, with many species failing to ignite at all; Additional Reading: Ignition times).
- They almost always have broad leaves, which are held horizontally to catch more than 70% of the incident sunlight.
- All of the canopy species have light-impermeable crowns and cast deep shade (EV 4-9 is usual);
- They can germinate and persist in deep shade.
- Those plants that comprise the primary species canopy are shade-dependent for their establishment, but are sun-dependent by the time they mature into adult trees and vines. Such species are frost tender when young, but as adults are relatively frost hardy (for the frost regime of their region and habitat)
- In contrast sub-canopy primary species (some vines, most ferns and many herbs) are shade-dependent all of their lives. These species are frost and exposure-intolerant and either die outright or die back and fail to thrive if suddenly exposed to full sun as the result of disturbance or extreme temperature events (especially when young), particularly to extremes of temperature >43-46^{o}C [for the lowlands of the warm temperate climate zone in south-eastern Australia (Additional Reading: Extreme weather: Figures AR116 and AR117)

- Canopy species are slow growing in low light conditions (deep shade), but show rapid growth where there is light to moderate shade or when a transitional shade gap appears overhead.
- Sub-canopy species are in contrast, relatively slow growing in deep shade, but virtually stop growing or die under higher light regimes.
- Most primary species are long-lived (many decades to centuries) and, remarkably, some species such as Soft Tree-ferns *Dicksonia antarctica* may live for millennia: growing tall, falling over, re-rooting, many times. In this manner, they effectively migrate ('walk') across the landscape
- Clearly, full shade is their forte.

Primary species have the following establishment requirements:

- Shade (mostly moderate to deep)
- Drought intolerance: often requiring higher moisture levels than either pioneer or secondary species.

General characteristics: The seed of primary species is generally short-lived and must gain a foothold for germination almost as soon as it is shed. Three types of seed production in this group are noted: erratic with large crops produced by different individuals from the same population in different years (e.g. Muttonwood *Myrsine howittiana*); continuous, where large crops are produced over long periods in consecutive years (e.g. some Figs *Ficus* spp.) and perhaps episodic, with most individuals producing large crops at the same time (Lilly Pilly *Syzygium smithii*). In contrast to all of the previous categories, primary species have long-lived leaves; some even allow ***epiphylls*** and lichens to become established (Figures S109 and S110, respectively). Lastly, most primary mature phase rainforest species are intolerant of frequent catastrophic disturbance (especially fire) and are simply expunged from the landscape if such disturbance regimes are the norm.

Examples of primary species include: Black Stem *Adiantum formosum*, Brush Bloodwood *Baloghia inophylla*, Prickly Currant-bush *Coprosma quadrifida*, Bolwarra *Eupomatia laurina*, Jasmine Morinda *M. jasminoides*, Jungle Brake *Pteris umbrosa*, Buff Hazelwood *Symplocus thwaitesii* and Lilly Pilly *Syzygium smithii*.

Uses: These are the last stage species that finish the successional race and complete the rainforest family: providing food and shelter to rainforest-dependent plant and animal species. It is essential that these species are included (or can get to your site) to complete the final phase of restoration.

Succession (provides free plants)

Succession is a key ecological ***theory*** and is easily observed in rainforest following disturbance. There are many disturbance types that vary in their intensity, extent, duration and frequency, with each rainforest ecological vegetation class being adapted to the usual suite disturbance regimes that characterise their habitat. Irregular, but catastrophic, disturbance occurs in rainforest as a result of flood (including tidal waves!) or fire (or land clearing) or it may be as minor as a small landslip or the collapse of a tree. Following a disturbance event in rainforest, succession begins to take place. This involves a group of pioneer and secondary plants quickly occupying the gap in the rainforest canopy (Figures S111, S112, S113, S114) that respond to either fire, soil disturbance or light. The plants that initially colonise these gaps are usually short-lived, sun loving and frost hardy. The interim phase is dominated by dying pioneer species and establishing secondary species. The shelter that the secondary species provide acts as a nursery crop that allows for the germination and establishment of primary mature phase rainforest plants that are shade-dependent and frost sensitive (Figure S111). The seed of pioneer and many secondary species are stored in the soil to await the next disturbance event, so by planting these species, not only do you protect the germinating primary rainforest species, you are also ensuring that the rainforest will be more likely to regenerate after any future disturbance. As the secondary species begin to die, the mature phase rainforest plants break through and repair the rainforest gap. This process is beautifully illustrated by Figures S112, S113 and S114.

The Restoration Manual divides up the common plants of south-eastern Australia's rainforests into pioneer, secondary and mature phase primary rainforest species. This then is the basis for determining the sequence in which they should be planted to mimic rainforest succession in nature (Chapter S6 Successional Planting). This advice is based on years of observation of plant behaviour and the response of rainforests to disturbance. Although these determinations are not 'fixed' (they do, and will, change as further information comes to light), you now have the tools to go out and determine the successional position of any species in your rainforest community. Given the findings in our Propagation Manual and the fact that our results sometimes concur with those of the literature, but often not, it is highly likely that you will discover successional classification differences for the same species on your site. This means that you have an ecotype that fits into a different place in the successional sequence, or that you have discovered a genuine misclassification. This illustrates the importance of not blindly accepting anyone's data or conclusions if it does not match your findings. Simply add your classification to the appropriate appendix.

Using this data should teach you that it is important not to skip a step in the restoration process. If you have missed out the pioneer plants at the start, then only weeds will germinate following the disturbance when your restoration site is flooded or burnt at some time in the future. Obviously leaving out the pioneers in your restoration efforts will be a waste of the whole restoration project. In addition you will find it more difficult to establish your secondary or primary species if you do not plant the pioneer species first up.

Pick pioneer species with different life expectancies and tolerances or face disaster
It is also equally important not to rely on too few pioneer species in your initial plantings. At least three shrub species and one tree species are needed. Remember that all living things have built-in expiry dates: and what you plant in one year will at some time in the future probably all die in the same year. In addition, each has its own special requirements. If one of these is not met, then the whole species planting can disappear off your site in an instant (Figures S115 and S116). With pioneer species that is something you can observe over very short time periods (1-10+years). We have learnt that lesson, so ensure it does not happen to you.

CAN YOU BELIEVE THAT A LEAF COULD LIVE LONG ENOUGH FOR A LICHEN TO GROW ON IT?

Figure S109. Bemm River, Victoria. The leaves of primary species such as White Supplejack *Ripogonum album* are so long-lived that epiphylls can establish on them.

Figure S110. Lake Wat Wat Game Reserve, Victoria. Foliose lichen growing on leaves of Large Mock Olive *Notelaea venosa*.

RAINFOREST REGENERATION CAN BE STARTINGLY RAPID

Figure S111. Goldsmith's in the Forest, Colquhoun via Lakes Entrance Victoria. This previously cleared spring soak on the upper margin of the Goldsmith's rainforest gully regenerated beneath a dense stand of the secondary species: Silver Wattle *A. dealbata*. The seed source (a mature rainforest remnant some 50m distant) has supplied copious amounts of rainforest seed to the site and succession has occurred. As the Silver Wattle nursery crop senesced (less than 20 years after regenerating following the cessation of vegetable growing on the site) primary mature phase rainforest seedlings began to establish, and these now dominate the site 5-8 years on from their establishment. They now have sufficient crown density and height to be able to resist frost and grow in full sun.

SUCCESSION MEANS FREE PLANTS: BUT YOU MUST SOMETIMES BE A BIT PATIENT, WATCH AND LEARN

THE WATTLES ARRIVE: THE CHANGE BEGINS

Figure S112. Goldsmith's property, Colquhoun Forest via Lakes Entrance Victoria. This is an old bean and pea growing enterprise. The site was chosen because of its warmth, flatness and friable soils. Years of ploughing depleted its organic carbon reserves and its fertility collapsed: the dense sward of Bracken *Pteridium esculentum* is the result: a species renowned for its capacity to thrive in low organic level sandy loams. Phase 1: gap-maintaining Bracken is colonised by Blackwood *Acacia melanoxylon* and Black Wattle *A. mearnsi:* both secondary species. This begins to shade out the light-dependent Bracken. This important process of gaps being over-topped by woody late secondary species is common in south-eastern Australia and is a major successional pathway in rainforest repair and recovery. It can occur as the result of fire, or in greenfields sites such as this one that have been previously cleared and then abandoned (as we also so found: see Figure 8.3)

BRACKEN DIES OUT: THE NEXT PHASE COLONISES

Figure S113. Goldsmith's property. Phase 2: the Bracken has been outcompeted by the wattles and the pioneer daisies: Common Cassinia *C. aculeata*, Shiny Cassinia *C. longifolia*, Three-nerved Cassinia *C. trinerva*, Snowy Daisy-bush *Olearia lirata*, Tree Everlasting *Ozothamnus ferrugineus*, Fireweed Groundsel *Senecio linearifolius*, Indianweed *Sigesbeckia orientalis* and Golden Everlasting *Xerochrysum bracteatum.* The daisies start to colonise as the wattles begin to senesce (20 years after germination). Now you know why you have to be patient! Still more patience is required because primary rainforest species colonisation is still a way off, with the Black Wattles still dominant on the site. The drought-tolerant daisies will persist until the wattles finally senesce and collapse. This is when the daisies will proliferate and provide a nursery crop that will nurture the new rainforest back: decades after its initial clearing for agriculture. Keeping the site free of transforming weeds during this successional process is a classic example of using the Natural Regeneration Method.

UNPALATABLE DAISIES HIDE RAINFOREST SPECIES

Figure S114. Goldsmith's property. Phase 3: is where the wattle collapse and the daisies take off. These unpalatable daisies, the fallen trees and soil enriched by decades of nitrogen and carbon from fallen wattle leaves will ensure that rainforest can grow on a previously ploughed vegetable field. Free from the gap-maintaining Bracken and protected from browsing, this gap is now being filled and repaired. Species present (but not obvious) include early secondary species: (Shade Plantain *Plantago debilis*, Rose-leaf Bramble *Rubus rosifolius*, Indianweed *Sigesbeckia orientalis*) and a late secondary species (Hazel Pomaderris *P. aspera*). The primary species now established are: Prickly Currant-bush *Coprosma quadrifida*, Large Mock-olive *Notelaea venosa*, Sweet Pittosporum *P. undulatum*, Forest Clematis *C. glycinoides*, and Wombat Berry *Eustrephus latifolius*, Scrambling Lily *Geitonoplesium cymosum*, Jasmine Morinda M. jasminoides, Austral Sarsaparilla *Smilax australis* and Tender Brake *Pteris tremula*, which will gradually create the mature rainforest.

<table>
<tr><th colspan="2">RELIANCE ON A SINGLE PIONEEER SPECIES CAN LEAD TO DISASTER</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure S115. Maringa Creek, Nyerimilang Heritage Park, Victoria. An early restoration attempt in the depths of winter showing the disastrous damage inflicted by frost on Kangaroo Apple. This site taught us two important lessons: do not rely on a single pioneer species and know your site conditions better than we did: before you start. Compare this with later more diverse (and frost hardy) pioneer plantings at the same site (Figures S292 (an earlier part of this lesson learned) and S296 with the site well on the way).</td><td>Figure S116. Demonstration Site, opposite Orbost, Victoria. Site 68 in the winter of 2004. This planting on the Demonstration Site for the Snowy River Rehabilitation Trial was a single species trial of Kangaroo Apple of the same age. The frost damage and their senescence in the same year was an important lesson. Compare this with a view of the Demonstration Site before another version of this lesson was learnt, but this time with primary species (Figure S288); and lastly a view where we had learnt the lessons) 2005 (Figure 7.7).</td></tr>
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If you rely on just one species, or only a few, that all die at the same time, you are in for a shock as weed invasion will be quick and will probably swamp your site. This is especially so along the edges or where your restoration work is constrained to narrow strips, such as at Site 68, which is the Demonstration Site for the Snowy River Riparian and Rainforest Restoration Trial (Figure S116). As a consequence, pioneer plantings should be diverse so they can accommodate a range of environmental conditions as well as ensuring that you have established a number of species with a range of life expectancies (Figure S117 and Figure S118). This lesson has been more successfully achieved with later plantings, such as on Site 70a on Marlo Road (Figure S119). Sequential death of pioneer and secondary species is much the preferred situation. This is because the death of a few plants at a time creates small gaps with transitory shade or full shade that favours regeneration of secondary and primary rainforest species that will then carry the site towards mature rainforest and away from further sun weed invasion.

Some shortcomings in applying succession principles in rainforest restoration

Natural processes of succession in rainforest at the scales that we apply to rainforest restoration (one to many hectares) would in nature, involve catastrophic disturbance. The features associated with such catastrophic disturbance differ to those on the rainforest restoration site in several important ways and these may have a significant bearing on your management of the site and its success. Table S5 lists these important features, how they differ to the restoration site, what complications they can cause, and how best to overcome these problems.

Ecosystem resilience

This is a very important concept in ***restoration ecology***. The theory is that ecosystems have resilience to degradation and that careful management and manipulation of the site to speed up recovery or succession can release this powerful force. This ecosystem resilience, or 'life-force' if you like, is usually best recognised by looking at remnant vegetation in the landscape. Often the system is just bursting to be released, but is held back by one or a number of ecological brakes. The most common brakes for rainforest in south-eastern Australia include: weed invasion, grazing/browsing or fire, and combinations of these, that reinforce the degrading process. Identifying the brake of the site, and doing something about it, will produce some amazing results (Figures S120, S121 and S122). In brief walk in on a 7-year-old restoration site in February 2009, the author discovered a tiger snake (located by the mobbing calls of Eastern Yellow Robin, White-browed Scrub-wren and Eastern Whipbird) and also recorded Rufous Fantail and Brown Gerygone. This means that just 7 years after the restoration work began, four insectivorous rainforest-dependent birds were encountered in a 10 minute jaunt (Appendix M1: worksheet: Two-way Table). How resilient is that!

EDGES MUST HAVE MULTIPLE SPECIES OR THEY WILL FAIL AND THREATEN YOUR SITE

Figure S117. Site 35 the Bike Track Marlo Road, Snowy River Victoria. Kangaroo Apple *Solanum aviculare* is beginning to senesce on a road edge. Because it was a single species planting and no succession has occurred, the site is now at risk from edge effects: the most obvious of which is weed invasion.

Figure S118. Site 35 the Bike Track Marlo Road, Snowy River Victoria. Inside the edge, every sun weed available has emerged. This is more than untidy: it is a threat to your restoration site. Always plant multiple species pioneer and secondary species to avoid this problem.

A very quick way to gauge your site's ecosystem resilience is to spray an area under a perch in proximity to a rainforest seed source. Perches include trees, shrubs, fence lines, and so on. If dispersal is occurring from the nearest rainforest stand to your site, then by removing this weed competition you can release abundant natural regeneration from the soil seed bank or from seed regularly voided by birds that use the perch. This has been very effectively used on many sites (Figure S123) and is especially useful where remnants still exist on or near the restoration site. Natural regeneration happens under any perch (Figure S124): even in sprayed Blackberry clumps or under your clothes line, which is a perch after all – just ask the person who does the laundry in your home (Figure S125). While on the subject of Blackberries: don't burn your sprayed clumps as these keep Black Wallabies at bay for three to four years, which is long enough to allow your palatable rainforest species to germinate and establish. You see, birds have been visiting your blackberry patch and sowing a rainforest for you (Figure S126). Careful observation of the natural regeneration on your restoration site during restoration (Appendix S4) will teach you heaps about ecosystem resilience in particular and rainforest ecology in general (Chapter 9).

Remnants

It is important to remember that remnants can exist in many different states. Some are more obvious than others (Table S6). An obvious one is a patch of bush, but less obvious is the remnant 'memory' left over from clearing as seeds dormant in the soil or the seasonal remnants of short-lived rainforest seed voided by animals every year at specific sites across the landscape.

Remnants come in many different sizes and forms. Areas of bush are fairly obvious and are the most useful remnants in terms of the amount of habitat and diversity of ***seed dispersers*** and plant species they can provide to your rainforest restoration site. This is simply a matter of size: the bigger the remnant, the larger the food and shelter resources are. This supports more species and attracts more to the site. This is most easily observed and explained through links observed in the field by conducting a bird census (Additional Reading: Bird breeding censuses). These show in exquisite and inter-linked detail, how birds start and complete their breeding cycles based on the resources available on the site. Even a young site has a lot to offer. Having a remnant, no matter how small, is important because it offers resources that your planting alone cannot hope to recreate at that point in time:

A REMNANT IS A GIFT FROM THE PAST.

Smaller remnants, such as individual trees, provide perches and perches mean birds and birds mean droppings and droppings mean rainforest seed (if a seed source is near enough). Remove the weeds (plus any other ecological brakes operating for the site) and rainforest begins to grow under your trees. If each tree out to the canopy edge is seen as a remnant, and weed control is applied, maybe much less of your site needs full restoration than you think (Table S6).

MULTIPLE SPECIES AND AGE EXPECTANCIES INCREASE THE CHANCES OF NATURAL REGENERATION

Figure S119. Site 70a Marlo Road, lower Snowy River Victoria. Already the Kangaroo Apple *Solanum aviculare* is beginning to senesce on this site (foreground), but other pioneer and secondary species are still healthy. The multiple species and age expectancies at this site include: Lightwood *Acacia implexa* (decades); Black Wattle *A. mearnsii* (20-23 years); Blackwood *A. melanoxylon* (40-60years); Blanket-leaf *Bedfordia arborescens* (decades); Musk Daisy-bush *Olearia argophylla* (decades), Hazel Pomaderris *P. aspera* (20-30 years) and Kangaroo Apple (5-8 years). Grey-headed Flying Foxes began roosting here two years ago while feeding on Kangaroo Apple (generally around February) and are present most years. That is a nationally threatened species turning up and camping after 3 years work! Partly as a result of that species visiting the site, and other dispersal mechanisms such as birds and wind, by 2007 nine pioneer and secondary species and nine primary species were natural regenerating in this restored site (Appendix S4: Natural regeneration: worksheet: Rainforest 2007).

The Blackwood remnant listed in Table S6 is one in particular that was (and continues to be) very rich in information. The wealth of information has grown over the years, so that we now understand that it is not just the tree as a remnant that was important. In addition, position in the landscape, the type of seed it had, its age, the presence of mistletoe and the abundant lichens that clothed its branches, all became considerations in a much larger ecological story about remnants: what they are and how they can help the rainforest restoration process. So when and what did we learn?

At first glance: beneath individual Blackwoods *Acacia melanoxylon* at Nyerimilang many species appeared once weed control was undertaken including Red Passion-flower *Passiflora cinnabarina*, which was predicted for the site, but known to be locally extinct (Table S6). The reasons for this took us a while to appreciate. The first relationship to reveal itself was that the trees were perches for rainforest birds to use and defecate the seed from fruit that they had consumed elsewhere in the landscape. But why did they choose to do it there? In addition, how could trees that were younger than the Eurabbie remnant hold as many bird-dispersed seed species (seven in all) and be further away from a rainforest stand and isolated in a paddock? All of these factors would suggest that this should not be so, except for one thing. At second glance: Blackwoods set seed with a fleshy ***aril*** that makes them very attractive to fruit-dispersing rainforest birds. So attractive in fact that they would cross open ground from the nearest intact bush to get there and feast on their bounty!

Years later, we were to realise three more factors from studies elsewhere in the region:

1. We began to understand the importance of mistletoes in the landscape in general and their role in assisting the natural regeneration of rainforest in particular (see Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes). You guessed it: the Blackwoods in question also had a number of mature Drooping Mistletoe *Amyema pendula* plants present. These are very attractive to a whole range of rainforest birds that eat rainforest fruits because they have either fruit or flowers that provide important food resources for most of the year. These continuous food supplies are rare in the landscape and appear very attractive to those rainforest birds that are able to move through fragmented landscapes in particular. And, as we found out, plant succession involving rainforest and fruiting species is easily demonstrated as is the role of honeyeaters in this process. These mistletoes are highly attractive to honeyeaters when they are in flower
2. Given the role of honeyeaters, our next realisation was to understand the importance of nectar alone for the establishment of rainforest fruiting species (see Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes). And that is how the Eurabbies could also have lots of rainforest fruiting species establishing beneath them: the birds first take a feed of rainforest fruit, then a sip Eurabbie nectar, while having a toilet stop in the tree, beneath which the bird has just sown the fleshy-fruited rainforest seed!
3. We had failed to record some very important vegetation that we had missed in the first assessment of what these Blackwood remnants (that are 20-30 years old) had to offer. This last surprise was not realised until 6 years after restoration works began on the Maringa Creek site at Nyerimilang. During a spring bird breeding census at the site, a local rainforest bird: Brown Gerygone *G. mouki* was recorded nesting beneath one of these trees. This is quite a coup as the site is very young for that to occur. That is when we realised the thing that was missing from our remnant species list: lichens. Because of the age of the Blackwoods, they had an extensive and diverse lichen flora present. It is one of these types (the fruiticose group) that this tiny rainforest bird was using to camouflage its beautiful dome-shaped nest.

At the smallest scale, individual tussocks often have an amazing array of species growing in them. For example, at Nyerimilang, Bergalia Tussock *Carex longebrachiata* retains large numbers of a broad range of species in different ***life-form*** categories from grasses to trees (Table S6).

So the message is: remnants are very important, and they come in all shapes and sizes, so seek them out and don't underestimate what they can provide and how many you may actually have on your site! They also grow and change with time as new species (trees, shrubs, mistletoes, vines, ferns, mosses, lichens, etc. all begin to arrive and establish). With each addition, they become a little more complex and are able to sustain a little more life for a little longer, until you have a functioning rainforest ecosystem restored on the site. The change is like having one tree (equivalent to a post-war Deli with one variety of cabbage for a couple of months a year) that morphs into an ecosystem of the complexity and resource richness of the Queen Victoria Markets, by which time everything has arrived and 'set up shop': and the rainforest crowds just keep rushing on in.

Conclusion

Effective application of restoration ecology and appropriate management on any given site can have some impressive and wonderful results. After only a short number of years following restoration works, the amount of natural regeneration appearing can increase dramatically. On the Snowy River, rainforest restorers were met with a solid sward of Kikuyu with a scattered overstorey of Mahogany and the occasional Black Wattle. The twin brakes of fire and grazing had limited the diversity and the number of species regenerating to a few patches along the steep banks of the river.

Restoration used both the Framework and Maximum Diversity Methods. Restoration workers on the Snowy River began by spraying the Kikuyu beneath remnant trees and planting. The number of species naturally regenerating increased from 13 in the first year to more than 100 by year five! This represents nearly 50% of the original rainforest plant diversity that would have been present on the site prior to clearing (Chapter 9: Natural regeneration). As a consequence, site management in later years has followed the Natural Regeneration Method of rainforest restoration, relying more on free natural regeneration than artificial and expensive planting and is now under ecological management.

Table S5. Differences between natural succession and rainforest restoration techniques.

Succession sequence	Natural scenario	Restoration scenario	Problems Solutions
Catastrophic disturbance	Immediate response: massed regeneration of native species.	Disturbance event a long time ago and a (usually much-depleted) soil seed bank of native pioneer species must compete with more numerous weeds.	Problem: Native species long-since depleted; weeds dominate. Solution: Future-proof your site by reintroducing native pioneer species to repopulate the soil seed bank ready for the next disturbance event.
Grazing/browsing pressure abates	Substantial loss of herbivores numbers (in fires or flood): leads to less pressure on regeneration: succession gets a head start.	Herbivore populations intact, or at higher levels, because of lack of predation and abundant food: any plantings or natural regeneration released can be quickly consumed.	Problems: Massive grazing and browsing of native plants. Solutions: Guarding; use of unpalatable species to control grazing/browsing pressure, exclusion (fencing) or culling.
Natural regeneration	High levels of natural regeneration follow.	Low levels of natural regeneration due to one or a combination of: weeds, loss of soil seed bank, remote seed sources etc.	Problems: Lack of recruitment; weed competition. Solutions: *supplementary planting* or *enrichment planting*; weed control.
Palatable species establish	High levels of establishment occur due to one or a combination of: reduced browsing after fire or flood, or camouflage by unpalatable or deterrent species.	Establishment of palatable species limited because of high grazing/browsing pressure. This can prevent the recruitment of important canopy and structural components of rainforests (trees, vines, shrubs, ferns etc.).	Problems: Palatable plants eaten. Solutions: Use unpalatable; camouflage, or deterrent species; alternatively plant and establish these species (accepting the browsing) in the knowledge that if you wait for a high rainfall year when grazing/browsing pressure will be at its lowest ebb, your 'sticks' will resprout and flourish.

Bellbirds: rainforest protectors?

Bellbirds have bad press in the fragmented landscapes of south-eastern Australia where they colonise areas of eucalypt forest with a dense shrubby understorey. The eucalypts can have high levels of psyllids and the lerp that they produce, and in some cases these eucalypt overstoreys die. This correlation is taken by many to be a direct cause and effect scenario, with the Bellbirds the culprits. So much so that this correlation has had a Preliminary Determination under the *TSC Act* (1995) as the threatening process: "Forest eucalypt dieback associated with over-abundant psyllids and Bellminers" otherwise known as Bellbird Miner Associated Dieback (BMAD). In some cases, the Bellbirds have been killed for it. Although there may be cases of a landscape 'out of balance' where Bellbirds show up, it is important not to 'throw all Bellbird colonies out with the rainforest bath water'. This is a classic case of ***correlation vs cause and effect***.

This bad press should not extend to Bellbirds and their role in rainforest ecology in south-eastern Australia, which may be crucial in rainforest dynamics in the region. It should be noted that the natural regeneration results reported in the Conclusion above happened beneath and within a Bellbird colony on Marlo Road on the lower Snowy River. We know from observations on that site that this process involved a myriad of small rainforest birds (supposedly hounded out of bush by Bellbirds).

A QUESTIONING MIND: THE BRAVE BEGINNINGS	HOLD YOUR BREATH: THE GAP APPEARS	RAINFOREST IS TRULY BORN: ALL IS WELL
		
Figure S120. Site 70b on the lower Snowy River, Victoria. In 1999, Ian McKeown's *over-spraying experiment* of the dense Kikuyu sward beneath this stand of remnant Southern Mahogany *Eucalyptus botryoides* led to the germination and establishment of 14 rainforest species including trees, shrubs, vines and herbs. This photograph was taken in 2004 when the Kangaroo Apple *Solanum aviculare* had been mature for 4 years. This site is 200m across the river from the nearest rainforest remnant (Lochend Jungle) on the lower Snowy River. Kangaroo Apple was the most dominant species and this has encouraged (along with our Maximum Diversity Restoration treatment of the site) a full-scale natural regeneration of diverse array of rainforest species. Compare this Figure S121 and S122. Up until 2007, this site has had recorded the following natural regeneration: 28 pioneer and secondary species (numbering tens of thousands) and 22 primary species by the hundreds of thousands (Appendix S4: worksheet: Rainforest 2007).	Figure S121. Site 70b Marlo Road, lower Snowy River Victoria. 18 months following the senescence of the Kangaroo Apple *Solanum aviculare* overstorey (8 years after it was regenerated) by Ian McKeown's experiment. Abundant natural regeneration has led to succession following restoration work. This work concentrated on addressing the key ecological brakes operating on this site: fire, grazing and weed invasion. Kangaroo Apple that germinated 8 years ago on this Snowy River restoration site has collapsed and died (18 months previously), and is being replaced through natural succession, without any further help. The plants arrived through bird and mammal dispersal. The species are Kangaroo Apple (red arrow) that germinated several months ago in full sun and Sweet Pittosporum P. *undulatum* (green arrow) and Lilly Pilly *Syzygium* smithii that germinated 4 years ago in the full shade. The Pittosporum will help to refill the gap, while the Lilly Pilly will develop into the mature Warm Temperate Rainforest canopy.	Figure S122. Site 70b on the lower Snowy River, Victoria. 30 months following Kangaroo Apple senescence (Figure S120). Compare the rapid growth of both the pioneers and the primary rainforest canopy species once the nursery crop canopy died 18 months earlier (Figure S121). The gap is now being rapidly filled, despite severe and ongoing drought (and without further management intervention). Naturally regenerating, gap-filling species within this frame include: Blackwood *Acacia melanoxylon*, Staff Creeper *Celastrus australis*, Tree Violet *Melicytus dentatus*, Weeping Grass *Microlaena stipoides*, Snowy Daisy-bush *Olearia lirata*, Sweet Pittosporum *P. undulatum*, White Elderberry *Sambucus gaudichaudiana* Fireweed Groundsel *Senecio linearifolius*, Kangaroo Apple *Solanum aviculare* and Lilly Pilly *Syzygium smithii*. Note that of these additional species, many of which were stimulated into action by the light reaching the ground, seven were from off-site dispersal from Lochend Jungle by birds, flying foxes and wind.

Amanda Dare's research (BMAD Working Group Newsletter 2008) reports that their presence did not affect bird diversity or abundance and that their presence alone did not increase psyllid abundance. Because Bellbirds do not disperse seed (HANZAB 2001), these rainforests would simply cease to function without the intercession of a broad range of other bird's that undertake this dispersal role. So we suspect that this 'Bellbird hounding' does not occur to any meaningful degree on most rainforest sites in south-eastern Australia.

REMOVE ECOLOGICAL BRAKES AND SUCCESSION WILL FOLLOW

Figure S123. Site 70b Marlo Road, lower Snowy River Victoria. This restoration site shows 8-year-old Kangaroo Apple *Solanum aviculare* that had died the previous year, and has been replaced without any intervention by Sweet Pittosporum *P. undulatum* and Lilly Pilly *Syzygium smithii* that had germinated some years before in the deep shade created by multiple canopy layers of emergent Southern Mahogany *Eucalyptus botryoides* and a dense and vigorous canopy of Kangaroo Apple (the perches and nectar/fruit attractions of this site). There will be no further natural regeneration of pioneers now that this position is deeply shaded by these primary canopy species. Contrast this situation with what occurs beneath the pioneers if the canopy species fail to establish in the first round of succession Figures S121, S122.

Take another example: that of the fire that occurred in 1952 around the foot slopes and ridges of Gulaga at Tilba Tilba. Following the fire, the eucalypts (mostly Yellow Stringybark *Eucalyptus muelleriana*, but also Coast Grey Box *E*. *bosistoana* and Forest Red Gum *E*. *tereticornis*) germinated and grew rapidly on the fertile rainforest-derived soils (Figure S127). These produced abundant lerps and the regenerating rainforest understorey in the gully attracted a Bellbird colony. Over time, their interaction with the lerps on the eucalypts managed to weaken many of the fringing eucalypts (mostly the Yellow Stringybark – a disturbance-dependent and short-lived species compared with its neighbours) with some dying in the apparent prime of their life (Figure S128) and the others following during recent droughts. During these droughts, the Bellbird colony moved from the original gully to the north of the Gulaga Walking Track across the intervening ridge (Figure S129) into more southern gullies, but have since returned to the home gully (Tanmaya pers. comm.). The fate of the eucalypts on the intervening ridge is quite another story: one that does not involve the activity of the Bellbirds (see Chapter 4: Rainforest expansion in a time of climate change) (Figure S129 and Figure S130).

Because eucalypts act as torches during bushfires, they have the potential to increase fire intensity (relative to the lower frequencies that are comfortable for rainforest species). Therefore their elimination from the margins of rainforests in the inter-fire period is advantageous to the rainforest stand (Figure S128 and Figure S130). In this way, the activity of Bellbirds can be seen as beneficial to rainforests. As the rainforest understorey expands outwards into the surrounding eucalypt community, this process actually facilitates rainforest expansion (as the competition from the eucalypts declines, their fire-propagating fine fuels are lost and replaced by less flammable rainforest litter (Additional Reading: Leaf litter: rainforest versus adjacent non-rainforest communities; and Table AR6). These advantages wrought by the Bellbirds include consigning the emergent eucalypts to an early grave (taking away their flammable bark and leaves) and reducing competition and facilitating rainforest canopy closure. This closure and the loss of eucalypts, helps to substantially reduce future fire risk to the core rainforest stand as both secondary and primary rainforest species colonise the site (Additional Reading: Ignition times). Make no mistake, during a period of climate change (and in the absence of fire), some rainforests are expanding in south-eastern Australia. Bellbirds appear to be assisting this expansion, as can be seen at many localities that include sites in usual rainforest habitat but which have had eucalypt colonisation following wildfire (e.g. some gullies on the lower Towamba River along the Snake Track). In addition, they also appear to be assisting in more open sites that in the past would have only had relatively small rainforest stands or rainforest elements. These include broad shallow gullies such as Whitakers Creek north of Narooma and the many foot slopes of ranges and hills in the Bega-Brogo valleys. Fragmentation and farming have reduced fire frequency and this absence of fire has led to a thickening understorey that appears to have favoured Bellbird colony establishment: allowing them to do their work. Don’t blame the birds: they are merely reacting to the landscape changes that we have wrought.

PERCHES COME IN DIFFERENT SHAPES AND SIZES

Figure S124. Brodribb River, Victoria. The planting behind the fence is 7 years old and abuts extensive tracts of Warm Temperate Rainforest along the river. The post that is used by larger rainforest birds such as Satin Bowerbirds *Ptilonorhyncus violaceus* and Pied Currawongs *Strepera graculina* has delivered us a new Lilly Pilly *Syzygium smithii* sapling!

Figure S125. Suburban clothes line, Lakes Entrance Victoria. These are classic examples of the role of a perch and bird-based dispersal of rainforest plants. This regurgitated pellet was left behind on the clothes hoist by a Pied Currawong *Strepera graculina* perching on the wires of the author’s clothes line and this particular one contained: Sweet Pittosporum *P. undulatum* and Cherry Ballart *Exocarpos cupressiformis*, though Pittosporum was only metres away, the nearest Ballart is more than 1km distant.

The other belief that these birds drive out other small birds is also a fallacy in south-eastern Australia’s rainforests. Censuses on the lower Snowy River showed that the richest sites for bird species also had Bellbird colonies present in the census area. This included both mature Warm Temperate Rainforest and 3-year-old restoration sites. There are a lot of things to worry about in the world: unless you can prove otherwise on your site or in your district, dismiss the

'Bellbird problem' from your mind and get on with the important job at hand. Enjoy them for what they are: a strongly territorial rainforest honeyeater that belongs. Enjoy their beautiful song and relax: they are assisting restoration.

Niches (who lives where and why)

Introduction

Niches are the homes preferred by a particular species: a place where they are most comfortable and able to thrive. Understanding niches is very important in rainforest restoration. For plants, a niche can be described in terms of one to several combinations of: climate, soils, slope, aspect, frequency of flooding, frequency of fire, amount of sunlight and competition from other plants, sensitivity to grazing and browsing. Some of the more important ones we will discuss in more detail.

DON'T BURN YOUR SPRAYED BLACKBERRY THICKETS

Figure S126. Tramway Creek, Nyerimilang Heritage Park, Victoria. Blackberry thickets provide a refuge from browsers for the germination of species such as these: Rainforest Geranium *G. homeanum*, Shrubby Fireweed *Senecio minimus*, Kangaroo Apple *Solanum aviculare* and Green-berry Nightshade *Solanum opacum* and many others including: important canopy species such as Blackwood *Acacia melanoxylon* and Boobialla *Myoporum insulare*. These important fruit-bearing species will bring other seed-dispersers to your old blackberry thickets and rainforest succession will be away!

Incident light niches (in nature and restoration)

At the floristic community level, plant composition is determined by one or a combination of: geology, soil type, exposure, salinity, elevation and position along a biogeographical or latitudinal gradient and other species present in the community (epiphytes require a host, etc.). Other factors that can also be important along major streams are the level and duration of flooding and alluvial deposition (Appendix S5). At the species level, not all of the components that make up a niche need to be known for it to be distilled into the key features that dictate where and when to plant a particular species to ensure a high level of establishment. For rainforest restoration, it is mostly about the amount of sunlight (and, conversely, shade), moisture and frost.

In Chapter S6: Successional planting, niche considerations are brought together and discussed along with the sequence for planting. Identifying and understanding niches is very important when undertaking rainforest restoration plantings. For the purposes of restoration planting, the amount of light is one of the most important. It is also a surrogate for exposure to the drying effects of wind and sun, soil temperature and the amount of frost a particular plant will get over the colder months. Experience has shown that establishment success is greatly enhanced (and therefore cheaper) if incident light niches (Table S7) and successional stage (Table S8) are understood, and used with species planting guides (Appendix S6) and an understanding seed set and maturation times (Appendix S7). Figure S131 provides a comparison of local light niches compared with full sun on a summer's day in Victoria. But remember that in the first 10-15 years following restoration, your planting will not look much like most people's idea of a rainforest because of your use of pioneer and secondary species that will 'husband' your real rainforest from the site as the primary canopy comes into its own.

Table S6. Examples of remnant types and what species they harbour.

Remnant type (Treatment)	Number recorded	Species recorded
	NYERIMILANG	
Creekline regrowth remnant (as found at the start of works)	42	*Acacia melanoxylon, Acaena novae-zelandiae, Acronychia oblongifolia, Diplazium australe, Atriplex prostrata, Calystegia marginata, Carex appressa, Carex longebrachiata, Celastrus australis, Clematis glycinoides, Coprosma quadrifida, Cyathea australis, Cyperus lucidus, Dichondra repens, Dicksonia antarctica, Einadia nutans, Einadia trigonos, Epilobium hirtigerum, Eucalyptus bosistoana, E. globulus , Geranium homeanum, Geitonoplesium cymosum, Melicytus dentatus* s.l., *Hypolepis glandulifera, Juncus spp., Lobelia anceps, Melaleuca ericifolia, Microlaena stipoides, Myoporum insulare, Oxalis perennans, Ozothamnus ferrugineus, Pittosporum undulatum, Polystichum proliferum, Rhagodia candolleana, Rumex brownii, Sambucus gaudichaudiana, Samolus repens, Senecio minimus, Sigesbeckia orientalis, Solanum vescum, Tetragonia tetragonioides, Urtica incisa.* Lichens: *crustose, foliose* and *fruiticose*.
Eurabbie *Eucalyptus globulus* ssp. *bicostata* (One spray)	15	*Acacia melanoxylon, Acaena novae-zelandiae, Clematis glycinoides, Dichondra repens, Einadia nutans, Einadia trigonos, Geranium homeanum, Melicytus dentatus* s.l., *Microlaena stipoides, Oxalis perennans, Pittosporum undulatum, Rhagodia candolleana, Rumex brownii, Sambucus gaudichaudiana, Urtica incisa*
Blackwood *Acacia melanoxylon* (Several targeted sprays)	14	*Acacia melanoxylon, Acaena novae-zelandiae, Amyema pendula Dichondra repens, Einadia nutans, Einadia trigonus, Geranium homeanum, Melicytus dentatus* s.l., *Microlaena stipoides, Oxalis perennans, Passiflora cinnabarina, Rhadodia candolleana, Rumex brownii, Sambucus gaudichaudiana.* Lichens: crustose, foliose and fruiticose.
Bergalia Tussock *Carex longebrachiata* (No treatment)	6	*Acacia melanoxylon, Acaena novae-zelandiae, Echinopogon ovatus, Geranium homeanum, Microlaena stipoides, Oxalis perennans, Rumex brownii, Urtica incisa*
	SNOWY RIVER	
Southern Mahogany *Eucalyptus botryoides* (One spray)	13	*Acacia dealbata, Acacia mearnsii, Acacia melanoxylon, Calystegia sepium, Celastrus australis, Cissus hypoglauca, Clematis glycinoides, Melicytus dentatus* s.l., *Morinda jasminoides, Pittosporum undulatum, Solanum aviculare, Syzygium smithii, Urtica incisa,*
Southern Mahogany *Eucalyptus botryoides* (4 year old restoration site)	100+	Species are listed in Appendix S4

BELLBIRDS TO THE RESCUE: RAINFOREST EXPANSION FOLLOWING THE 1952 FIRE

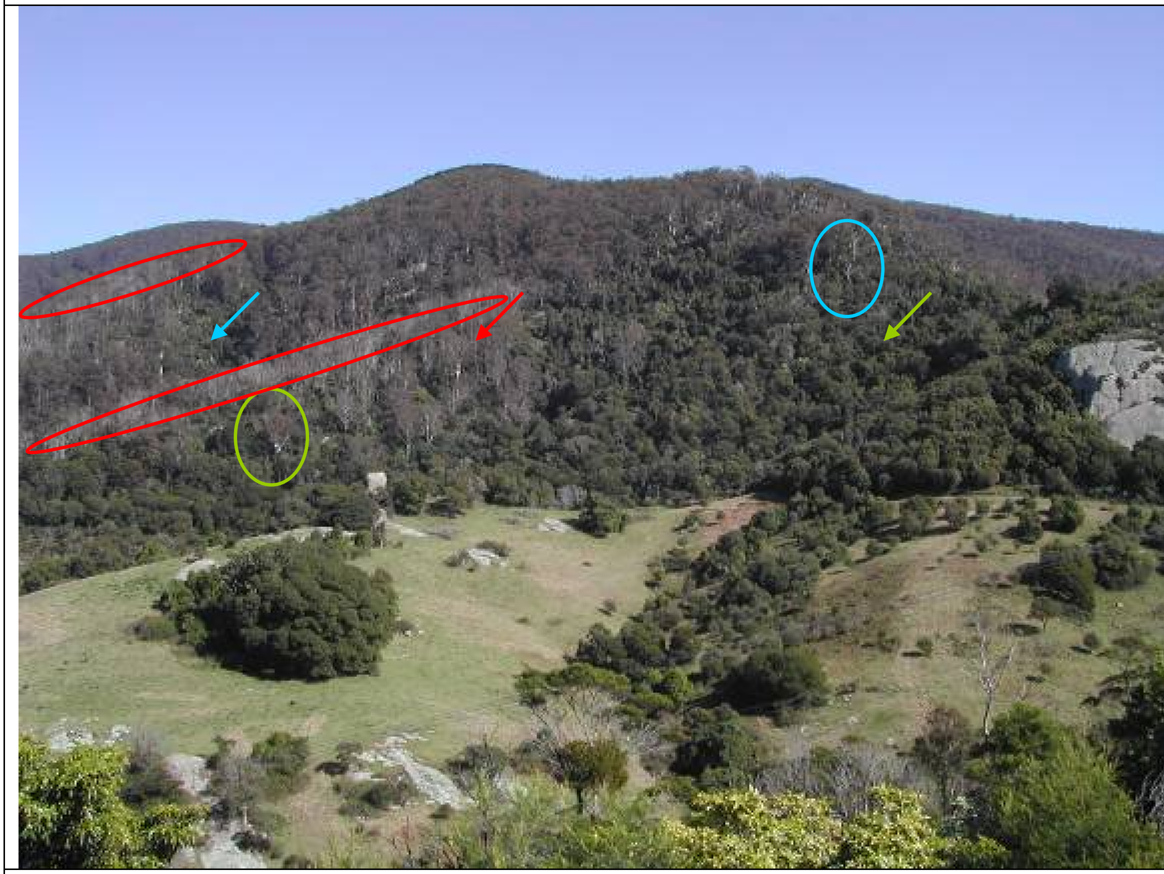

Figure S127. Gulaga Tilba Tilba, New South Wales. Following fire, the core Subtropical Rainforest zone on the mountain remained eucalypt free (green arrow). The gully (blue arrow) and ridge line (red arrow), were burnt and eucalypts invaded them following the fire. Clearly though, they are now retreating: aided by rainforest colonisation, perhaps the Bellbird colony and periodic drought. The dieback of the eucalypts on the ridge has had no Bellbird involvement (Tanmaya pers. comm.) and is entirely species-specific and drought-driven. The disturbance-dependent Yellow Stringybark *Eucalyptus muelleriana* is dead or dying (red ellipses), while the ***cohort*** of longer-lived disturbance-independent species: Coast Grey Box *E. bosistoana* and Forest Red Gum *E. tereticornis* (green ellipse) are doing fine and are actually sporadically regenerating as rainforest gaps form and the surrounding Yellow Stringybarks die out each drought (see Chapter 4: *Rainforest expansion in a time of climate change* for details). The dieback of the eucalypts in the gullies is Bellbird-correlated (blue ellipse). **Note**: the blue arrow of this Figure is the area photographed in Figure S128.

SUBTROPICAL RAINFOREST AND DRY RAINFOREST EXPANSION AT GULAGA IN A TIME OF CLIMATE CHANGE

DROUGHT STYMIES EUCALYPTS; RAINFOREST COLONISES	RAINFOREST MOVES IN	BELLBIRDS, DROUGHT AND TIME MAY PROTECT RAINFOREST
		
Figure S128. Gulaga Walking Track Tilba Tilba, New South Wales. The death of these eucalypts in the gully to the north of the walking track is Bellbird-correlated. The process began with eucalypt invasion of the margins of the Subtropical Rainforest stand following the 1952 fire. The rainforest understorey began to re-establish and became suitable habitat to a Bellbird colony. After successive droughts, these emergents that should have been in the prime of their lives, succumbed and died. The exact pathways, causes and effects involved in this complicated ecological process are yet to be settled. However, whatever the cause, this process of eucalypt thinning in the margins of rainforest stands improves the chances of survival of the rainforest when the next wildfire sweeps across the valley, reducing the chances of canopy fire in a ***crowning fire*** or the ignition of a ***bonfire tree*** deep within the rainforest. For the landscape perspective see Figure S127.	Figure S129. Gulaga Walking Track Tilba Tilba, New South Wales. Here on a ridge, the first stage of rainforest colonisation is complete: pioneer, secondary and primary species have established and the eucalypt overstorey from the 1952 fire has died out. At this point, the primary species have developed (but the canopy of these species is patchy), with the gaps caused by eucalypt and wattle senescence once more being occupied by pioneer and secondary species as the succession towards Subtropical Rainforest continues apace and the sclerophyll past fades before our eyes.	Figure S130. Gulaga Walking Track Tilba Tilba, New South Wales. Drought-mediated decline in eucalypts and the early stages of the colonisation of Subtropical Rainforest species. In time, the more drought-tolerant rainforest species establish on this east aspect site and as competition increases over succeeding droughts the less-drought-tolerant eucalypts become more moribund and eventually die (as has happened further down slope) in Figure S129. For the landscape perspective: see Figure S127.

Table S7. Incident light* niches, the species which occupy them and their characteristics.

Niche eV	Full sun eV: 17	Transitory shade + shaded open sky gap eV: 17-12	*Light shade* eV:13-15	Moderate shade eV: 10-12	Deep shade eV: 4-9**
Sun					
Shade					
Structure	Large gaps, north facing river banks: maximum hours of sunshine.	Gaps with incomplete shading, which leads to a bright gap at some time and full sun at others. A gap receiving morning sun means species planted should be able to cope with light shade; in contrast a gap receiving afternoon sun means species should be planted that are able to cope with full sun.	Whether the shade cast by light-permeable canopies is light or moderate, is species dependent. The crowns of a wide range of pioneer and late secondary species provide light shade (Table S8). As an example, the mature crowns of Coast Tea-tree and Sweet Pittosporum provide moderate shade niches.		Deep shade cast by Lilly Pilly, young Blackwood, young Sweet Pittosporum or multiple canopy layers.
Successional stage	Early pioneer stage.	Variable (because of gaps). Pioneer species in late afternoon sun niches, light-tolerant mature phase primary species adapted to heat (Rusty Fig) and those not: if frost is not an issue then (Pittosporum, Yellowwood etc.) in morning sun niches.	Late secondary stage. Late secondary species that can be planted include Stinging Tree, Hazel Pomaderris, Blackwood, Red Ash, Blanket-leaf, Brush Kurrajongs, etc. The shade that they in turn cast, allows for the establishment of mature phase (primary) species that are shade-dependent such as: Jasmine Morinda, or frost intolerant species such as White Milk-vine.		Climax stage. This allows the establishment of deep shade dependent species such as: Lilly Pilly, Brush Bloodwood, Buff Hazelwood, Bolwarra etc. and shade and moisture dependent ferns such as: Lady-ferns, Black-stem Maidenhair, Jungle Grape, and Lacy Ground-ferns.
Species tolerances	Sun dependent. Frost hardy.	Variable depending on time of day sun exposure occurs: sun or shade-tolerant, frost-hardy or frost-sensitive.	Shade dependent. Frost sensitive. Most seem to need cool soils to establish.		Shade dependent. Moisture dependent. Frost intolerant.
Types of species suited to the niche	Mostly pioneer species includes wattles, daisies and eucalypts, and often include species from the Cool Temperate Rainforest flora that occupy frosty gaps in the warmer lowlands.	Morning sun: see column to the right; afternoon sun see column to the left.	Mostly secondary species and tougher (non-moisture dependent) primary species can be established.		Only mature phase primary species.

*For ease (and accessibility) of measurement a "Sekonic Digi Lite F" incident light meter was used. All readings are in electron volts (eV) on a setting for 400ASA film

**4EV is for young Lilly Pilly *Syzygium smithii*, 9EV is for young Blackwood *Acacia melanoxylon* (see Table S8). The type of measurement device is not essential for your own tests as long as you use the same device in all situations.

Table S8. Incident light niches as they relate to successional stage, crown condition and species.

Class EV range	Species	Full (deep) shade EV 4-9									Moderate shade EV 10-12			Light shade EV 13-15			Partial sun EV 16	Full sun EV 17+
Emergents	Blue Gum *E. globulus* ssp. *bicostata*																M	
	Coast Grey Box *E. bosistoana*																M	
	Kurrajong *Brachychiton populneus* (Tree is rain-green deciduous)															M	Crown regrowing	Deciduous state
Pioneer species and long-lived late secondary species	Cherry Ballart *Exocarpos cupressiformis*														Y			
	Coast Wattle *A. longifolia* ssp. *sophorae*													Y		S		
	Rough-barked Apple *Angophora floribunda*													M				
	Coast Banksia *B. integrifolia*													Y		M		
	Giant Honey-myrtle *Melaleuca armillaris*													Y/M/S				
	Tree Broom-heath *Monotoca elliptica*													Y/S				
Open sky gap	Shaded (but open to the sky) ‘bright’ gap												-					
Late secondary species	Coast Tea-tree *Leptospermum laevigatum*											M						
	Blackwood *A. melanoxylon*									Y					M/S			
Mature phase canopy species	Sweet Pittosporum *P. undulatum*				Y						M						S	
	Lilly Pilly *Syzygium smithii*				Y		M											
Full sun	Sun (February Eastern Daylight Savings)												D/E	8.30am	Varying degrees of light cloud			9.30am-17.30pm
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17 and 17+
		eV																

Crown age: Y=young; M=mature; S=senescing. Full sun: D=dawn; E=evening.

INCIDENT LIGHT NICHES FOR A SUMMER'S DAY

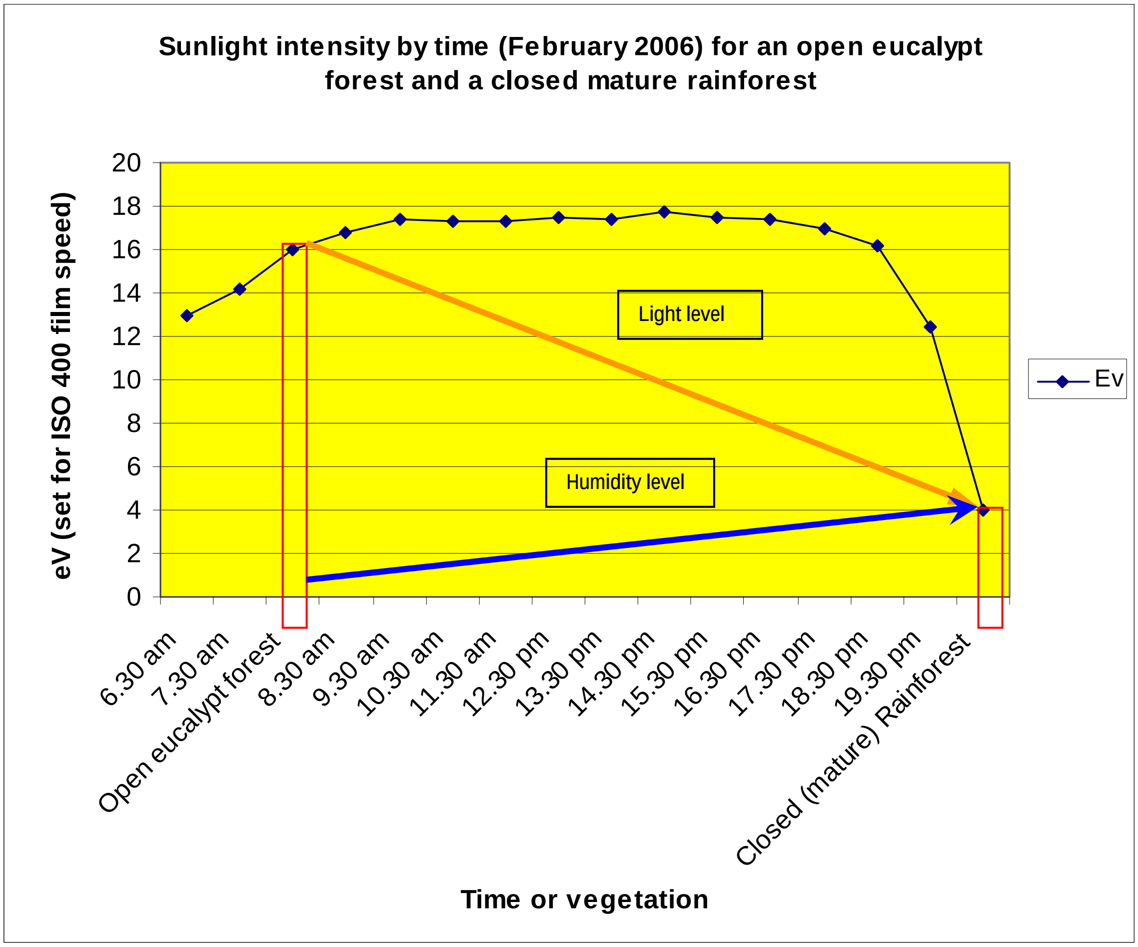

Figure S131. Incident light readings in full sun for a summer's day in Victoria. Note the correlation between light shade of EV 13-15 and time of day, as well as the differences between open forest and mature rainforest (by comparing them) with Table S8 and you start to get the idea. Light levels: Humidity levels below the canopy:

The importance of shade is critical in rainforest restoration as many species have very specific requirements for their establishment and successful growth (Figure S132). If these requirements are ignored then the plant will either fail to establish or fail to set seed: either scenario is a waste of time and effort (Figure S133). Others may survive and reproduce, but their growth may be retarded and consequently their usefulness for the creation of shade may be limited and the amount of seed committed to the soil seed bank or available as food and for dispersal via animals may be greatly reduced (Figures S134, S135).

The planting niches for a range of species are discussed at some length. This is because of their importance and the fact that adhering to planting recipes that recognise them will produce better results, more quickly and cheaper, than if you ignore them (compare Figure S136 with S137 and Figure S138 with S139). Remember that incident light niches are a surrogate for other important factors such as soil temperatures (Sue Reagan pers. comm.). Many rainforest plants have shallow roots and high soil temperatures and/or moisture stress will lead to the death of both secondary and primary species that can otherwise tolerate full sun if a mulch, shaded soil surface (appropriate light niche) or unlimited water is provided (as in the nursery; Richard Vuat pers. comm.). Because the latter is rarely possible, ignore light niches at your peril (compare Figure S132 with Figure S133).

IGNORING PLANTING RECIPES HAS SERIOUS IMPACT: IF IT INVOLVES SOIL MOISTURE AND TEMPERATURE

Figure S132. Maringa Creek, Nyerimilang Heritage Park, Victoria. This is an example of Musk Daisy-bush *Olearia argophylla* planted at the same time (but in the correct planting niche) as those in Figure S133 which have established and grown very well (and have consequently not been wasted). The reason appears to be superficially about shade, but this also has an impact on soil temperature and moisture availability. This helps to explain the contractor and nursery observations that a subset of these (mostly secondary species), are grown in full sun in nurseries: but the soil is shaded (cool) and water is never limiting.

Figure S133. Maringa Creek, Nyerimilang Heritage Park, Victoria. The importance of understanding light niches and individual plant requirements as they relate to gap dynamics is well illustrated in this photo. A rainforest restoration contractor has failed to follow the recipe to plant: "*Bedfordia arborescens* and *Olearia argophylla*: in shade of *Senecio* or *Ozothamnus* etc. (not under wattles)". The reason for the planting niche being so specified is that these secondary species die in full sun: they were planted in November and the photo was taken in late December when they were close to death (being dead by January).

THE IMPORTANCE OF LIGHT NICHES

Figure S134. Mitchell River Walk, Bairnsdale Victoria. Even though this plant is a primary species, transitory afternoon shade on a dry site is important for its successful establishment and subsequent growth. This specimen is a growth-retarded Kangaroo Apple that is 3 months old growing in afternoon sun, only metres away from the plant in Figure S135. The difference is that there is no afternoon shade. As a consequence, it failed to thrive, did not set seed in its first year and remained stunted and died early. Such a specimen is wasted on the site; choosing a species that tolerates full sun would have been a better option.

Figure S135. Mitchell River Walk, Bairnsdale Victoria. The same species planted in afternoon shade meters away from the one pictured to the left. It is a healthy 3 month old Kangaroo Apple that flowered and set seed in its first year, grew luxuriantly, flowered and fruited regularly, grew to full dimensions and powered on for several years. This specimen is of much greater use to the rainforest restorer than the stunted one to the left, because it set more seed, shaded more area for longer and consequently controlled more sun weeds and attracted more wildlife.

Full sun (EV 17+)
This is the hottest, driest and most exposed niche in rainforest. In the absence of major disturbance it is a rare niche in mature rainforest. But after catastrophic disturbance, usually wildfire (but also landslides, flooding, and even ***tsunamis***: depending on rainforest type) it can actually be the dominant niche (Figures 3.8 and 3.9). It is occupied by a range of the most sun-dependent and exposure-hardy pioneer species that provide the nursery crop for the establishment of secondary species and then the recovery of the mature canopy. Some (but not all) of these species are also common after disturbance in the broader non-rainforest landscape. They are generally characterised by having narrow leaves (a moisture-conservation and frost tolerance adaptation). Good examples of the plants that fill these niches include members of the daisy family: Groundsels *Senecio* spp., Tree Everlastings *Ozothamnus* spp., Golden Everlasting *Xerochrysum bracteata* and Tall Everlasting *Helichrysum elatum* and Cassinias *Cassinia* spp. Within days of the disturbance, these species respond by germinating and then transforming this full sun niche to one of transitory shade or full shade. This begins the process that ensures that primary and secondary species that are more shelter-dependent can germinate (or be planted) and help repair the rainforest gap (Figures S132 and S133).

INCIDENT LIGHT NICHES: IGNORE THEM AT YOUR PERIL

Figure S136. Johns Street, Lakes Entrance Victoria. This Muttonwood *Myrsine howittiana* seedling (a primary canopy species) is planted in full (moderate) shade and is thriving and went on to establish.

Figure S137. Johns Street, Lakes Entrance Victoria. This Muttonwood *Myrsine howittiana* seedling was planted in full sun within metres of the specimen in Figure S136 but over the following year it died. This is because it is a primary species that requires full shade to establish.

Transitory shade: full sun to shaded open sky gap (EV 12-17)
This is a combination of full sun and full shade as the sun passes overhead. The timing of the full sun can be critical (Table S7). Full sun in the morning (the coolest part of the day) equates to the light shade niche described below, whereas full sun in the afternoon (the hottest part of the day) equates to the full sun niche previously described (Table S8).

Niches such as these develop as the result of small-scale disturbance within the rainforest or on its margins. They occur as a result of wind throw of whole trees or limbs, or the death of individual trees or small groups of them. For a general description of the types of species that occupy transitory shade niches consult the relevant niche (above or below) depending on the time of day that the gap is exposed to the sun and Appendix S6: All species+FCs (and all planting Appendices).

Light shade (EV 13-15)
A few of the canopy-covered light shade niches we have measured include areas beneath a range of pioneer canopy species, such as Kangaroo Apple *Solanum aviculare*, mature or senescing late secondary species such as Blackwood *Acacia melanoxylon* and both young and mature-crowned Coast Banksia *B. integrifolia*. In addition, this niche can also develop under any senescing rainforest tree or pioneer species not already mentioned where crown thinning is characteristic prior to the plant's death.

Moderate shade (EV 10-12)
There are two habitats that provide these light levels: those that are covered by a canopy of specific pioneer or late secondary species; and those that are in full shade, but open to the sky (Table S8). This niche is gloomier than the light shade niche, but brighter than that cast by the primary rainforest canopy species that create the deep shade niche. Species that we have measured that provide moderate shade include: mature canopied Sweet Pittosporum,

Coast Tea-tree *Leptospermum laevigatum* and open to the sky shaded gaps. You should obtain a light meter and test others too.

The open-sky niche forms on the southern side of densely-canopied areas of rainforest. Although there seems to be a degree of commonality in species compositions between these two sub-niches there are also some differences (Table S9). In general, the species occupying moderate shade niches tend to have broader leaves than the pioneer species that are abundant in the full sun niche (being dominated by secondary and primary species).

PLANT RIGHT FIRST TIME	
	
Figure S138. Johns Street, Lakes Entrance Victoria. This healthy two-year old primary species: Lilly Pilly *Syzygium smithii* was planted in light shade and has grown well and set seed in the following year.	Figure S139. Kinkuna, Lakes Entrance Victoria. This unhealthy specimen of Lilly Pilly *Syzygium smithii* planted in full sun is clearly in trouble as its sunburnt appearance illustrates. Its condition over summer is also a warning that if a moderate or repeated mild frosts arrive in the following winter: this plant will die.

Table S9. Two moderate shade niches: an open sky gap and one beneath the canopy and their typical species.

Sub-niche	Usual species	Characteristics
Moderate shade beneath canopy	Actively growing: Yellowwood *Acronychia oblongifolia*, Prickly Currant-bush *Coprosma quadrifida*, Muttonwood *Myrsine howittiana,* Sweet Pittosporum *Pittosporum undulatum* and Lilly Pilly *Syzygium smithii* Dormant: Blanket-leaf *Bedfordia arborescens*, Musk Daisy-bush *Olearia argophylla*	Frost-protected; higher levels of humidity.
Open to the sky shaded gaps	Actively growing: Musk Daisy-bush *Olearia argophylla*, Blanket-leaf *Bedfordia arborescens*, Austral Mulberry *Hedycarya angustifolia*, Hazel Pomaderris *Pomaderris aspera*, Elderberry Panax *Polyscias sambucifolia*, Yellow Elderberry *Sambucus australasica*, Victorian Christmas Bush *Prostanthera lasianthos* Dormant: none	Frost exposed, heavy and frequent dews even over summer, though moisture levels due to humidity are lower during summer days or high winds.

Deep shade (EV 4-9)

This is the gloomiest part of the mature rainforest where shade weeds lurk. This niche is occupied by specialised species that operate under low light conditions. These species include many ferns such as Austral Lady-fern *Diplazium* *australe*, Fragrant Fern *Microsorum scandens* and some woody species such as Yellowwood *Acronychia oblongifolia*, Bolwarra *Eupomatia laurina,* Buff Hazelwood *Symplocus thwaitsii*, Mountain Pepper *Tasmannia lanceolata* and Lilly Pilly *Syzygium smithii*. Some of these species (particularly ferns) are also humidity dependent. When a canopy gap is created, the young canopy species that have previously established in deep the shade beneath the original canopy now grow rapidly into the breach now open to the sky. In contrast, the deep shade-dependent species such as Austral Lady-fern *Diplazium australe* or Bolwarra *Eupomatia laurina* are severely disadvantaged by the development of a gap (especially if it is in full sun) and may suffer or die if the gap is not rapidly shaded by pioneer species.

Moisture niches

Most rainforest plants have quite specific moisture requirements. Some tolerate a wide range of moisture regimes (although these may represent specific ecotypes, so always match your niche with plants propagated from the same niche elsewhere in the region). Many others do not have such tolerance and an incorrect choice will spell doom for that plant. Remember to match both light niches (Appendix S6) and moisture niches (Appendix S6: worksheet: Moisture niche). The 'doom' may be years in coming, such as the next drought: so be very careful with this advice.

Emergent trees

Each emergent tree group is usual to a particular rainforest ecological vegetation class or floristic community. There are seven groups of emergent trees in the lowland rainforests of south-eastern Australia: banksias (Littoral Rainforest), cypress pine (Littoral Rainforest), eucalypts (Warm Temperate Rainforest, Littoral Rainforest), figs (Subtropical Rainforest), kurrajongs (Dry Rainforest) Sheoaks (Gallery Rainforest, Warm Temperate Rainforest and Littoral Rainforest) and wattles (Cool Temperate, Warm Temperate, Subtropical, Gallery, Littoral and Dry Rainforests). Many of these species are leviathans and all act as touchstones for rainforests providing resources that are often not available or common in the dark and murky depths of the canopy-shrouded rainforest below. Such resources include: nest sites for the largest of rainforest birds (e.g. Sea Eagles *Haliaeetus leucogaster*); nectar; perches; and lookout points that attract specific birds such as ***raptors*** (eagles, goshawks, falcons etc.), Dollarbirds *Eurostomus orientalis*, and Rainbow Bee-eaters *Merops ornatus*. Because of their size and longevity, many emergents can provide hollows that are both large and persistent: lasting decades or even centuries and providing nest sites for transregional migrants (Table AR 9).

Banksias

In the south-east, Coast Banksia *B. integrifolia* is the only rainforest species in Littoral Rainforests where it is an emergent of 30m height (Figure S140) as well as acting as a nursery crop species by adding prodigious amounts of organic matter with its proteoid roots (Figure 4.29). It can also extend inland on to limestone cliffs around estuaries and along rivers. Elsewhere in eastern Australia it grows up in to the mountains in Cool Temperate Rainforest (e.g. the New England Tableland) or Warm Temperate Rainforest (Comboyne Plateau). It is an extremely reliable nectar producer, providing regular winter flowerings that fuels the coastal migrations of many ***blossom-nomads*** including two threatened species: Swift Parrot *Lathamus discolor* and Grey Headed Flying-fox *Pteropus policephalus*. Apart from its nectar production, old trees provide nesting hollows for Crimson Rosella *Platycercus elegans* as well as other hollow-dwelling birds and mammals. Its budding marks the end of summer, and its flowering: the arrival of autumn.

Cypress pine

The local species is Oyster Bay Pine *Callitris rhomboidea* and is represented as a late secondary species in the lowland rainforests of south-eastern Australia (in both Victoria and in New South Wales, where found in Littoral Rainforests of some dunes, cheniers and sea cliffs) as well as further north on the Mid North Coast. Its ecology and habitat are similar to the more widely known examples of the Subtropical Rainforests further north where the species is Brush Cypress *Callitris macleayana* and in the Monsoon Rainforests of Northern Australia where the species is *Callitris intratropica* (Bowman 2000).

Eucalypts

Eucalypts in particular provide a myriad of unique foraging opportunities not available from other species in rainforests. These opportunities include nectar, their bark and their leaves (Figure S70). Some even produce manna from their leaves (which is an exudate of the leaf's sap that is concentrated on its outer surface through drying to become a rich source of carbohydrate). In addition, they provide a broad range of hollows (sizes, types: trunk or spouts) and they host mistletoes (Figure S141) that often start hollows. Mistletoes are a major food and nesting resource in the landscape and their role in hollow formation is an added bonus. Eucalypts represents some of the largest and longest living trees in the rainforests of south-eastern Australia and they rely on a range of disturbance regimes for their regeneration (Figure S142). Disturbance can be extensive and damaging to all of the rainforest (fire), but it can also be relatively confined (such as with landslip, mobile dunes or as ***flood-mud regenerators*** on streams).

One particularly important role of eucalypts is to provide a stopping-over point in seasonal and diurnal migrations for landscape nomads that transfer rainforest fruits between rainforest stands (and your restoration site). Many bird species rest there before moving on and, in fragmented landscapes, this behaviour is particularly important in linking nearby rainforest stands with more isolated areas of bush. This vital linkage helps to keep rainforest islands genetically strong and diverse by transferring propagules from site to site.

COAST BANKSIA AND LITTORAL RAINFORESTS	EUCALYPTS PROVIDE UNIQUE RESOURCES
	
Figure S140. Lake Bunga, Victoria. Multi-aged Coast Banksia *B. integrifolia* in Littoral Rainforest provide a multitude of resources to the rainforests in which they grow, not least of which is their contribution to soil development.	Figure S141. Bunga Creek, Victoria. The mistletoes (red foliage) begin hollow-initiation in their emergent rainforest eucalypts hosts (that as a team) supply additional nectar, fruit, nesting sites, and foraging opportunities that are a bonus to rainforest fauna.

Figs

Figs are considered to be a keystone species. They produce huge amounts of fruit over very long periods and are consequently a major focus for a wide range of fruit eating animals and birds. They can occupy very tough niches including rock scree, rock tors and sea cliffs (Figure S37). They help protect such rainforests from fire because of the shade they cast, the low ground-fuels they maintain (Figure S38) and the low flammability of their foliage (Additional Reading: Ignition times). In addition, several are strangler figs and can begin life high up in the canopy (see Stranglers): effectively producing a 'high rise apartment' for additional habitat diversity. In Subtropical Rainforests (where moisture is not a limitation) they can support vast aerial gardens of epiphytes.

Kurrajong

This tree plays a very special role in the development of Dry Rainforest. It is a very drought-tolerant tree that can germinate in the crevices of rocks and is able to drop its leaves during dry periods (a phenomenon known as being rain-green). It is extremely long-lived and produces a broad crown and copious amounts of leaf litter. Their seeds are covered in a nutritious powder that is irresistible to many rainforest birds. These birds that are attracted to the crowns of such trees bring with them the cargo of rainforest seed from whatever they have just been eating. They stop for a rest, defecate and miraculously you have a rainforest! Another unusual role is that the new leaves are eagerly consumed by Rainbow Lorikeets.

Sheoaks

Sheoaks play a similar role to that of wattles (see below). They do not have ***bacteria*** fixing their nitrogen, but ***blue-green algae***. However, unlike most wattles of rainforests in south-eastern Australia (Blackwood being an exception), the sheoaks are important hosts to a wide range of epiphytic orchids and some ferns.

Two Sheoaks occur in rainforests in south-eastern Australia. Swamp Oak *Casuarina glauca* is a common nursery crop for some floristic communities of Littoral Rainforest that are associated with brackish estuaries, as well as for some stands that occur on both sedimentary and gabbro headlands. It is well adapted to rainforest life being wind-dispersed and an emergent tree. It also regenerates in rainforest gaps via root suckers. It is an extremely salt and exposure-hardy plant. The other species is River Oak *Casuarina cunninghamii*, which is restricted to the margins of rivers (particularly sandy streams north from Bega). It is a giant of a tree and can be found as an emergent over Gallery Rainforest along the margins of streams as well as on higher river flats nearby where it is an emergent over *Sand Rivers* Warm Temperate Rainforest (Figures S16 and S17), which mirrors its habitat in Subtropical Rainforests on rivers.

EMERGENT EUCALYPTS ARE THE CROWNING GLORY OF MANY RAINFORESTS IN SOUTH-EASTERN AUSTRALIA

Figure S142. Arandene, Kalimna Victoria. Emergent eucalypts provide important resources to rainforest species in south-eastern Australia. Although they most commonly regenerate after fire, in some rainforests of our region, they regularly regenerate after landslips and flooding. In fragmented landscapes such as this they are stopover and lookout points for rainforest fruit-dispersers that move through open landscapes (particularly Pied Currawongs *Strepera graculina*, Topknot Pigeons *Lopholaimus antarcticus* and Satin Bowerbirds *Ptilonorhynchus violaceus*). What they drop (when they stop for a spell), may be the start for your rainforest on your restoration site or lead to its enhancement.

Wattles

Wattles are very important in rainforests, but not all are emergents. Wattles can become abundant after disturbance: particularly fire or flood, when they germinate *en masse* and help repair the damage brought on by the disturbance. These keystone species achieve this in several ways:

- They fix nitrogen
- They produce copious amounts of leaf litter that further enriches the soil
- The young pods are eaten by a range of mammals, the beautiful Ganga Gang Cockatoo *Callocephalon fimbriatum* and the unripe seeds are eaten the spectacular King Parrot *Alisterus scapularis*
- Their seed is a major food source for many rainforest pigeons
- The arils on rainforest species (Lightwood *Acacia implexa*, Coast Wattle *A. longifolia* ssp. *sophorae*, Sallow Wattle *A. longifolia* ssp. l*ongifolia*, Blackwood *Acacia melanoxylon* and Maidens Wattle *A. maidenii,*) all provide valuable energy for a broader range of rainforest animals. For Blackwood this larder is all the more valuable because it hangs on the tree for a further 6-8 months following seed set
- Their pollen attracts myriads of insects that in turn supplies food for a host of others
- The gum produced by Black Wattles *Acacia mearnsii* following the damage from wood borers is essential winter food for Sugar Gliders (Strahan 1995)
- Wattle grubs are an important part of the diets of Yellow-tailed Black Cockatoos *Calyptorhynchus funereus*
- The ***symbiotic*** relationship between Silky Hairstreak *Pseudalmenus chlorinda* butterflies and the larval attendant ants *Anonychomyrma biconvexa* is facilitated when these grubs produce feeding gallery hollows in Blackwoods *Acacia melanoxylon* that are colonised by these ants within 4-7 years of planting. This wattle is the butterfly's larval food plant (Braby 2004)

- They have special protein-producing glands that sustain insect predators such as wasps and ants through times when their usual foliage-damaging prey of grubs and caterpillars are scant.

Emergent wattles include: Cedar Wattle *Acacia elata,* Frosted Wattle *A. frigescens* and Blackwood *A. melanoxylon.*

Stranglers

Stranglers are trees that use a host plant in order to germinate and establish well above the ground and in that process, eventually kill the host through strangulation. The time taken for this to occur is species and habitat-specific. For some species, this is an advantage (especially those that are palatable) as it places them out of the reach of browsers, and in a favourable light niche. Traditionally in Australia, the term has been applied to Figs in the genus *Ficus* (Figure S143). There are ***obligate stranglers*** and ***facultative stranglers***. In south-eastern Australia, the term equally applies to a number of other species: Blackwood *Acacia melanoxylon*, Sassafras *Atherosperma moschatum,* Black Wattle *Callicoma serratifolia,* Banyalla *Pittosporum bicolor* and Possumwood *Polyosma cunninghamii* that begin life as stranglers on Soft Tree-ferns *Dicksonia antarctica* (Figure S144) – a perspective verified by Floyd (2008).

Interestingly, the term is also applicable to one species of vine, that (unlike the other species mentioned) germinates on the ground, but later runs up trees and forms the classical interlocking strangling latticework of stems on the host. This species has been observed to kill thin-barked rainforest canopy trees such as Muttonwood *Myrsine howittiana*, Sweet Pittosporum *P. undulatum* and Lilly Pilly *Syzygium smithii*. In combination with the strangulation of the canopy species this vine's dominance of the groundlayer as well: causes the death of large areas of rainforest (e.g. Kalimna Gully, Lakes Entrance). Can you guess which species it is? The culprit is English Ivy **Hedera helix*. This devastating impact has not been observed on eucalypts presumably because their bark is thicker. Interestingly there are at least two other native species (Common Silkpod *Parsonsia straminea* and Giant Pepper Vine *Piper hederaceum* var. *hederaceum*) that climb their hosts with adventitious roots, but fail to produce the strangling stem lattice of English Ivy; in fact, in most cases the stems detach with age with the vine itself being supported in the canopy by younger vine stems (Common Silkpod) or by draping over branches in the canopy (Giant Pepper Vine).

The importance of eucalypts in rainforest ecology

Introduction

In the ecological context, eucalypts are considered an integral part of rainforest in south-eastern Australia. Within the rainforests of this region, some species are unable to regenerate without fire, but their role is no less important. Others (Blue Box *E. baueriana,* Coast Grey Box *E. bosistoana,* Southern Mahogany *Eucalyptus botryoides,* River Peppermint *E. elata,* Blue Gum *E. globulus,* Manna Gum *E. viminalis* and Red Ironbark *E. tricarpa)* are able to regenerate in the absence of fire. Such regeneration events are associated with bank failures, flooding or landslips.

The ecological role of eucalypts in rainforest is important in its own right. This role includes flowering (pollen and nectar), foraging sites for bark gleaning birds and mammals and hollow production. Their occurrence in rainforest fire refuges and the fact that they often escape fires that devastate the rest of the adjacent landscape means that their resources remain available when all else is barren. The fertility of rainforests soils usually means that they reach enormous dimensions and ages in these habitats. In many of the drier districts of the region, this results in resource provision (large hollows, abundant mistletoe crops, foraging and nesting sites) during periods of landscape stress such as droughts or fires. These resources may be at very low levels or absent in such landscapes during and after these events. These refuges help to sustain animal populations and provide a wellspring for recolonisation after major disturbance events.

The presence of these emergent eucalypts, however, provides disadvantages for rainforests in terms integrity following fire incursion (Floyd 2008), especially where the species involved are ***bonfire trees*** (see Chapter S7: Fire management at the local scale).

Food resources

Eucalypts provide a wealth of food resources. These are often species-specific and can include: nectar, pollen, manna, foraging sites for bark gleaning animals, leaf and bark litter that harbour invertebrates, frogs and reptiles. Their fallen limbs provide a large carbon store that is used by fungi to fuel their important nutrient recycling role as they convert minerals bound up in the ground litter into mineral nutrients that can again be used by plants. These limbs are in turn broken down by beetles, grubs and other invertebrates that are the favourite food of Eastern Whipbirds *Psophodes olivaceous* (Figure 9.1). Eucalypts being very important in this regard because their wood is dense and persists for decades.

Nest sites for raptors and others

Many birds of prey rely on eucalypts for nest sites and nest materials in rainforests. Locally these include: White Bellied Sea Eagle *Haliaeetus leucogaster*, Grey Goshawk *Accipiter novaehollandiae* and Whistling Kite *Haliastur sphenurus*. The dense rainforest canopy appears to provide the privacy that these birds require when breeding. The sheer size of many of the raptor nests means that there are few other trees in the landscape that develop to the size required to provide the strength to support such structures. In order to attain these dimensions in the drier lowlands, these trees occur (more often than not) in rainforests: especially along river flats and nearby gullies. Others birds that nest locally in rainforest located in these habitats include species such as Australian Ravens *Corvus coronoides* and White-faced Herons *Egretta novaehollandiae*, which rely on eucalypts to supply not only nest sites, but nest materials as well (Chapter 9: Opener).

Australian Ravens are a very significant species in Littoral Rainforest ecology in south-eastern Australia. This is because they feed on the wattle and ***berry***-bearing shrubs of the coastal dunes and return several times a day to the escarpment rainforests in the nearby hinterland to roost, preen and defecate. In so doing, they transport a wide range of coastal species to these rainforests and help maintain them as Littoral Rainforests rather than Warm Temperate Rainforest. The Littoral Rainforest species currently recorded as being transported in this manner include: Coast Wattle *Acacia longifolia* ssp. *sophorae*, Coast Beard-heath *Leucopogon parviflorus*, Common Boobialla *Myoporum insulare* and Seaberry Saltbush *Rhagodia candolleana*.

STRANGLERS USE OTHERS TO GET TO THE TOP

Figure S143. Natchanuka, New South Wales. This Small-leaved Fig *Ficus obliqua* began life as a seed deposited in the fork of a Brush Bloodwood *Baloghia inophylla* Small-leaved Fig is an example of an obligate strangler within Subtropical Rainforest that (at least in south-eastern Australia), is rarely observed beginning life as a ground-dwelling seedling. The germination point is marked by the red arrow and is many metres above the ground.

Figure S144. Rainforest Centre, Orbost Victoria. This Blackwood *Acacia melanoxylon*, like several other species of Cool Temperate and Warm Temperate Rainforest trees, uses Soft Tree-ferns *Dicksonia antarctica* as the host, which in time is strangled. In the case of the highly palatable Blackwood at least, the advantage to the strangler is to begin life beyond the reach of species that eat them such as Swamp Wallaby *Wallabia bicolor*. The other advantage is that it can sit above the gloom and thrive in the filtered sunlight offered by this niche. Blackwood is a facultative strangler. The point of germination on the tree-fern trunk is marked by the red arrow and is at about 1.5m.

Hollows

Although many trees in south-eastern Australia form hollows, few rival eucalypts for the number of hollows that they contain, their range in sizes, their longevity and their diversity of types. There are many hollow-dependent species of birds, mammals, frogs and reptiles across the landscape (although obviously they are more abundant in the nearby sclerophyll forest communities). However, the features of the hollows found in eucalypts that occupy rainforests are specifically useful to particular species for the following reasons:

- Their size
- Their durability (related to tree age and their preservation in fire refuges)
- Their presence in the habitat used by the hollow's residents for other needs such as shelter (large forest owls) or for hunting and feeding (raptors, mammals, etc.).

Hollows, water and drought

Irrespective of the hollow's origin (or the tree species in which they are generated), hollows can perform other vital functions. Some hollows may be water tight (e.g. in Swamp Oak *Casuarina glauca*) and these provide vital watering and bathing points for animals (particularly birds). These 'water-hollows' differ in several ways from the usual ground-based water sources (streams, ponds, puddles etc.). They are usually shaded beneath the canopy and the water often has a small surface area to volume i.e. they are deep and narrow clefts, (which ensures that evaporation is reduced and the water supply persists for longer) than is the case for puddles on the forest floor. Because of their relatively small size and their large catchment (the tree's canopy), the occasional rainfall episodes during droughts are more likely to be captured by these hollows, whereas the same rainfall event may not reach the ground and, if it does, it soaks away into the ground and is lost to the animals of the rainforest. Many animals (mammals, amphibians and birds) may benefit from such 'drought-proof' water sources.

Water conserved in hollows is likely to be especially important to a range of taxa in Littoral Rainforests where surface water sources are rare (steep ground: causing run-off or permeable soils failing to allow ponding) or, the groundwater seepages are contaminated by salt. Although many species (particularly birds) can, and do, bathe and obtain water from dew-fall off the leaves of the rainforest canopy, such water supplies are limited, erratic and can also be salt-contaminated in Littoral Rainforests. For reliable, long-term water sources, water-hollows may be valuable during drought (in all rainforests), but are vital in Littoral Rainforests, leading to many species seeking them out and using them on a daily basis (as has been observed with Little Wattlebird *Anthochaera chrysoptera*) and have been noted as ensuring the survival of species such as Superb Lyrebirds *Menura novaehollandiae* (Higgins *et. al.* 2001).

Rainforest gaps

Rainforest gaps are fundamental to the ecology of rainforests. They are the places where a vast diversity of the rainforest flora begins life (with 79% of all of the study areas' rainforest species found there) and they are the crucibles of rainforest repair. So, from both a process and biodiversity perspective they are very important. Rainforest gaps can be bright, shady (Figure S145), warm, hot, dry, frosty, and dynamic. They provide niches and resources (Figure S146) that are not present in mature rainforests. For this reason, it is very important in rainforest restoration to conserve gap species when restoring your site, so do not shade them out, and let nature deal with them over time. Fortunately because we are not completely efficient at producing a mature rainforest during restoration, many gaps will be left. So for this reason a few unplanted gaps are not failures, but a bonus.

Other niches

There are a range of other niches worth discussing (as, in many cases, your works will be creating them). There are quite specific features for each of these niches and their ecological roles are many and varied. Basically the more niches and the more diverse they are, the greater will be the diversity of the plants and animals that can live in or use the rainforest that you create.

Rainforest canopy

The rainforest canopy is like your skin. It provides a barrier against sun and wind, but allows moisture and gases to pass through. This maintains a stable moist and shaded internal atmosphere in the rainforest beneath its canopy that allows a plethora of specialised plants and animals to exist in an otherwise parched and sun-drenched land.

Different rainforest canopies have significantly different qualities depending on the individual species. For example, Sweet Pittosporum *Pittosporum undulatum* is the favoured roosting site for Powerful Owls *Ninox strenua*. In contrast, Lilly Pillys *Syzygium smithii* are favoured by another species (see Vine tangles below) and Chapter S2: Figures S82.

Vine tangles

Even though these areas in a rainforest are a pain to navigate, they provide important habitat for many animals and play a pivotal role in keeping damaged areas of rainforests free of fire. Vine tangles in trees also provide roosting habitat for Sooty Owls *Tyto tenebricosa* (which would roost in caves if they were available), seeming to like the dark, especially if the tangle is in Lilly Pilly *A. smithii* (Rowan Bilney pers. comm.). It is unusual to see them backlit as in Figure S82.

Golden-tipped Bats *Kervoula papuensis* fly through vine tangles where they forage on spiders, rather than using the more open flyways favoured by other forest bats. This species is a rainforest specialist roosting in the abandoned domed nests of Brown Gerygones *G. mouki*. Their grizzled gold-tipped fur provides the perfect camouflage for the lichen and moss-lined exterior of the Gerygone's nest.

Epiphytes and moisture-dependent plants

These plants have very specific niches and some surprising ecological roles to play. Not all can be accommodated in the early stages of rainforest restoration (irrespective of the method employed), and currently none are routinely 'planted'. It is planned to attempt this in a 7-year-old restoration sites along the Snowy River over the next couple of years.

SHADED RAINFOREST GAPS: THE CRADLE FOR A REPAIRING RAINFOREST CANOPY

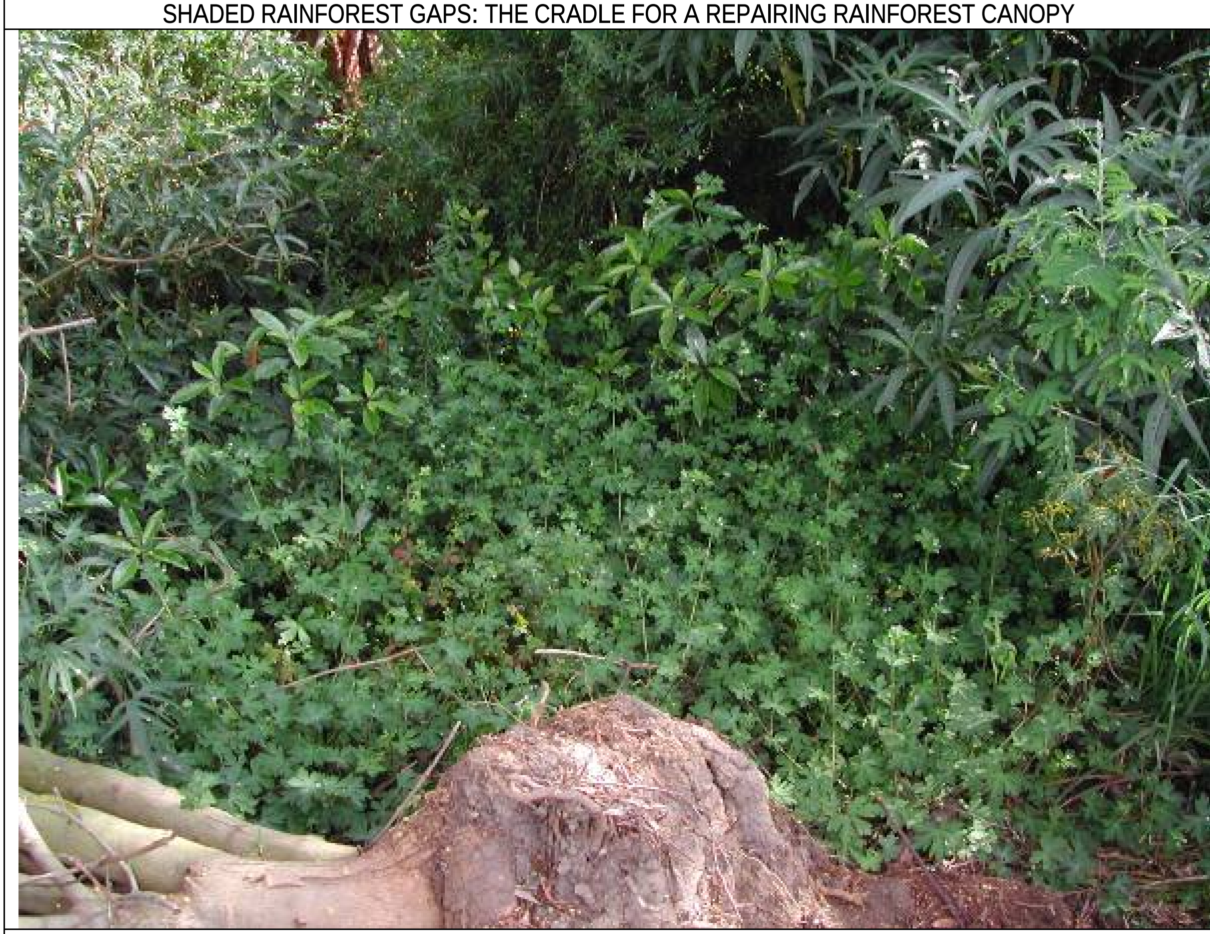

Figure S145. Marlo Road, Snowy River Victoria. This is a shaded gap in a restored stand of Warm Temperate Rainforest beneath the secondary species Black Wattle *Acacia mearnsii* that is maturing and giving way to the next generation of canopy species. It shows just how different rainforest gaps can be compared with mature rainforest (Figure S31). Because it is shaded, it provides ideal habitat for species that thrive in shade and/or are frost sensitive (Cinquefoil Cranesbill *Geranium potentilloides*, Tree Violet *Melicytus dentatus* and Kangaroo Apple *Solanum aviculare*), many of which will ultimately take over the role of providing the mature canopy of the rainforest stand (here, Blackwood *Acacia melanoxylon*, Sweet Pittosporum *P. undulatum* and Lilly Pilly *Syzygium smithii*). The value of this site lies in the fact that it demonstrates the value of Bradley Weeding because this very spot was weeded using this method a year before when Prairie Grass **Bromus catharticus* was removed to favour cranesbill. It is only 1m from a bright north-facing sunny edge along a road (see Figure S146), but is protected by the shade of the mature Black Wattle, which has maintained the gap's integrity despite the road edge being dominated by the Prairie Grass.

KEEP RAINFOREST GAP SPECIES WHEN DOING RESTORATION: THEY ARE IMPORTANT HABITAT

Figure S146. Marlo Road, Snowy River Victoria. This stand of Common Reed *Phragmites australis* was a colonial gap species present on the site prior to restoration works beginning and it was conserved because of the importance of rainforest gaps and the species that they conserve. In this instance the Reeds provide habitat for Clamorous Reed Warbler *Acrocephalus tentoreus*: a beautiful and melodic summer breeding migrant that lives and nests in these patches. The dead stems contain insect larvae that are fed on over winter by Crested Shrike-tits *Falcunculus frontatus*: another beautiful bird that uses mature rainforest as well, but relies on such gap species during periods when other resources may be scant. Reeds also provide ideal habitat for Large Bindweed *Calystegia sepium;* its flowers provide gathering places for small beetles that fertilise them (Figure 8.26). The resulting seed is a staple in the diet of Swamp Rats *Rattus lutreolus* during autumn. Swamp Rats act as seed dispersers because they store seed in caches for the winter, but their forgotten caches may end up germinating.

Epiphytes

Epiphytes can be broadly grouped into non-vascular (mosses and liverworts) or vascular (ferns, orchids and other flowering plants). The former will arrive when conditions are right (humidity, hosts and light levels). From experience, lichen species are the first: arriving in as little as 4 years in humid environments on the Snowy River (Figures S147, S148). However, mosses such as *Rhaphidorrynchium amoenum*, and several leafy liverworts, take a little longer (in the order of 10-15 years) on the secondary species of these drier and more exposed marginal bluffs following Framework Restoration plantings of their Littoral Rainforests (Figures S149, S150). Some of these non-vascular epiphytes are particularly important as nesting material for many birds. For example, Silvereyes and honeyeaters use mosses to construct their delicate nests. In fact, the breeding of birds that use lichens to camouflage their nests (Rose Robins, for example) is related to the establishment and development of these epiphytes on your restoration site (Additional Reading: Bird breeding censuses). This includes the species illustrated in Figures S149, S150. Because some of these mosses and lichens hide the nests from predators (Figure S151), breeding success is likely to depend on these epiphytes being present and, as importantly, a lichen-covered site to place the nests to complete the camouflage process because where such sites are missing, the nests of such birds stand out badly and breeding fails. See Additional Reading: Bird breeding censuses and the case of the hapless Yellow Robins on the Top Flat at Maringa Creek, Nyerimilang that lacked the lichen-festooned sites for their lichen-covered nests (Figure AR78).

Some ***vascular epiphytes*** (such as Fragrant Fern *Microsorum diversifolium* and Kangaroo Fern *M. pustulatum*) can be propagated and planted in the soil, but they either require mature trees to provide sufficient moisture retention in spongy bark (that is fed from the crown of the host), or they need high sub-canopy humidity to establish on substrates because much of their moisture is derived from the atmosphere. Their nutrients come from the air (in the rain): as the fine organic dust that rains down continuously; the atmospheric dust from rotting wood; and from insect frass (faeces) common in the rainforest. Consequently, such epiphytes are more common in old rainforest than in younger stands. Birds that use epiphytes in nest construction are listed in Table S10. Some larger epiphytes that lend themselves to being established by the rainforest restorer are listed in Table S11.

A TRIUMPHAL MOMENT: THE ARIVAL OF A RESTORATION SITE'S FIRST EPIPHYTES!

Figure S147. Site 70f Marlo Road, Snowy River Victoria. Four years after establishment, this Forest Clematis *C. glycinoides* hosts its first fruiticose lichen epiphyte that when mature, are used to camouflage nests of some ***rainforest dependent birds*** (e.g. Figure AR78).

Figure S148. Site 70f Marlo Road, Snowy River Victoria. Four years after establishment, this trunk of Southern Kurrajong (Blackfellow's Hemp) *Commersonia rossii* hosts a group of fruiticose lichen epiphytes.

Provided there is sufficient atmospheric moisture, trunk-size does not seem to matter for spongy-barked species (Musk Daisy-bush *Olearia argophylla* and Lilly Pilly *Syzygium smithii,* etc.). With high humidity, well-developed spongy bark (e.g. Lilly Pilly) (Figure S152) is not a necessity, but for some hard-barked species, such as Blackwood, the bark does need to be well developed and the crown needs to be able to funnel onto them sufficient water and nutrients from regular rainfall. For some reason, most epiphytes also require low light levels, though ***lithophyte***s deal well with full sun.

Experimentally, Rock Felt-fern *Pyrrosia rupestris* has been successfully established on 15 year old Coast Banksias *B. integrifolia* and Blackwoods by "planting" it in the forks of trunks that show obvious signs of moisture funnelled down from the crown. This can be judged by looking for this effect following light rainfall events. Similarly Kangaroo Fern *Microsorum pustulatum* has been established on the spongy-barked Common Boobialla *Myoporum insulare* (Figure S153).

All of these requirements are in short supply in the early stages of rainforest restoration, so, in general, it is not recommended that much time be spent on introducing vascular epiphytes onto your restoration site before the other requirements (humidity, bark or crown development) are in place. They will arrive when and if your restoration efforts have succeeded and matured. Those ferns that begin their epiphytic life by establishing in the soil (*Microsorum* spp.) are an exception to this general rule and can be established as soon as there is a primary species canopy cover to provide the deep shade and the atmospheric moisture that they require for their survival.

Other moisture-dependent plants

Rainforests are home to many other moisture dependent plants (particularly mosses and liverworts) that are not epiphytes, but which are used as nesting materials. Golden Weft Moss *Thuidiopsis furfosa* (Figure S154) is just one example and it used by Bassian Thrushes *Zoothera lunulata* for nest structure and as insulation for the eggs (Figure S155), rather than nest camouflage, while for others they are the major structural components (Figure S155).

EPIPHYTES SHOW THAT YOU ARE SUCCEEDING AND ENSURE RAINFOREST BIRDS CAN BREED

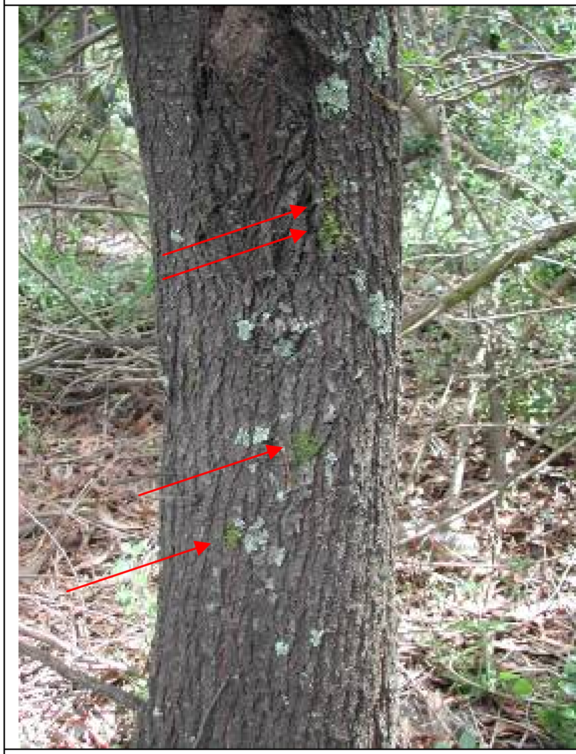

Figure S149. Golf Links Road, Lakes Entrance Victoria. Fruticose lichens, liverworts and mosses on Blackwood trunk in full deep shade at Kinkuna site 17 years after the planting of the host tree. The differences between the lichen abundance and the presence of leafy liverworts (red arrows) on this trunk compared with the trunk in Figure S150 may be accounted for by one or a number of factors: lower light (8 Ev), higher humidity, larger tree (bigger crown to water the trunk), and/or more mature bark.

Figure S150. Golf Links Road, Lakes Entrance Victoria. Fruticose lichens are abundant in this light shade gap (12.5 EV) on a Blackwood trunk in transitory shade at the Kinkuna site 17 years after planting the host tree. Note the absence of leafy liverworts on this trunk. These require higher levels of atmospheric moisture (a feature lacking in this gap) but present in the deep shade in Figure S149. Other factors that may contribute are: a smaller crown (less surface watering of the trunk), and less mature bark.

Mosses and ferns: when and how they arrive

Mosses and ferns are most common and diverse in moist environments (and, in most cases, this means rainforest), though, even in the most droughty sites with rainforest (Dry Rainforests and Littoral Rainforests), species from both groups occur there (just in smaller numbers and diversity). The universal feature that unites these two groups, however, is the need for moisture to begin life. Mosses and ferns both require water to reproduce: for the transmission of the male gametes or sexual cells ('sperm' if you like) in ferns.

The other interesting thing is that ferns often arise out of moss beds (and frequently on clay banks: the reasons for this will become a little clearer as you read on). We have been waiting for a while for mosses and ferns to show up on our restoration sites. Though these plants do appear on restoration sites as young as 5 years of age (Figures 10.2-10.4), the mechanism for establishment has been unclear until the June floods of 2007 on the Snowy River. Within weeks things really began happening (Figure S156). Moss germination (and succession leading to the germination of ferns) was just not occurring and this baffled us. The sequence, however, is that the mosses of Warm Temperate Rainforest in these virgin niches, which began as fields of Kikuyu **Pennisetum clandestinum* just 5 years earlier, have difficulty establishing in the leaf litter that our plantings quickly produced (see Figure 9.20). What is needed is a leaf-litter free, moist clay surface (non-vascular epiphytes in general require establishment niches that are free of leaf litter; unless the small leaf-sized litter fall does not swamp the moss as is the case with Kunzea (Figure S156). Floods also provide these 'clean virgin niches' repeatedly over time after inundation, whereas vertical clay banks collect no leaf litter and therefore provide a more perennial niches for moss colonisation and fern succession (see Figure 10.4).

LICHENS ARE GOOD CAMOUFLAGE FOR THE NESTS OF RAINFOREST ROBINS AND OTHER SPECIES

Figure S151. East Gippsland, Victoria. This range of lichens growing on a young Sweet Pittosporum *P. undulatum* illustrates the three types: fruiticose (green arrow), foliose (red arrow) and crustose (yellow arrow). Only the fruiticose lichens have been observed to be used as camouflage on the nests of rainforest birds (such as Rose Robins *Petroica rosea* (above left), while foliose lichens (like some mosses) are used for structural components in bird nests in south-eastern Australia (see Figure S155) as well as for some honeyeaters. Even flies (upper right) resemble lichens in rainforests! (Photos: Robin and fly – Rohan Bilney).

Table S10. Rainforest birds of south-eastern Australia that use non-vascular epiphytes in their nests.

Bird species	Use in nest building*	Epiphyte group
Black-faced Cuckoo Shrike *Coracina novaehollandiae*	Camouflage	Lichens
Cicadabird *Coracina tenuirostris*	Camouflage	Lichens
Mistletoe Bird *Dicaeum hirundinaceum*	Camouflage	Lichen
Eastern Yellow Robin *Eopsaltria australis*	Camouflage	Lichens+mosses
Crested Shrike-tit *Falcunculus frontatus*	Camouflage	Lichens
Brown Gerygone *Gerygone mouki*	Structure+camouflage	Mosses+lichens
Yellow-faced Honeyeater *Lichenostomus chrysops*	Structure	Mosses+leafy-liverworts
Brown Cuckoo Dove *Macropygia amboinensis*	Camouflage	Mosses
Lyre-bird *Menura novaehollandiae*	Lining+structure	Mosses
Black-faced Monarch *Monarcha melanopsis*	Camouflage	Mosses
Rose Robin *Petroica rosea*	Camouflage	Lichens
Rufous Fantail *Rhipidura rufifrons*	Structure	Mosses
Lewins Honeyeater *Meliphaga lewinii*	Structure	Mosses+lichens
Eastern Spinebill *Acanthorhynchus tenuirostris*	Structure	Mosses
Large-billed Scrub-wren *Sericornis magnirostis*	Structure	Mosses
Silvereye *Zosterops lateralis*	Structure	Mosses+leafy-liverworts

*Sourced from Pizzey and Knight (2003); Frith (1979) and the observations of the author.

We have also noticed that mosses are colonising the Maringa Creek rainforest restoration site on (as yet) un-flooded clayey soils beneath a Framework Restoration Method planting where both pioneer and secondary species have been established in the last 5-6 years. These shrub and tree species have shaded out the pasture grasses, bared the soil and removed the competition for the mosses. A number of species are involved (two of which are tentatively identified as *Calliergonella cuspidata* and *Thuidium sparsum).* The advent of these moss species as well as the presence of fruiticose lichens on the remnant Blackwoods on the Bottom Flat has allowed Brown Gerygones *G. mouki* to nest there this year as well (Additional Reading: Bird breeding censuses). This is a very pleasing outcome probably arising from a number of factors: vaulted canopies beneath the 20-30 year-old Blackwoods for foraging; the lichens growing on their trunks and branches to provide the camouflage lichens for their nests; and the Framework Restoration Method plantings that have provided the structural component mosses (*T. sparsum*) for the nest to be constructed. Gerygones were not recorded breeding on the Bottom Flat when the Blackwoods were in a sea of pasture grasses for the 2 years before restoration works being undertaken.

Parasites

Parasitic plants: essential rainforest resources

Parasites can be classified as obligate (those species that cannot live without their host, such as mistletoes) or facultative species (those that can live without the host but do not always do so, such as Cherry Ballart *Exocarpos cupressiformis* and Sandalwood *Santalum obtusifolium*). If the prospect of encouraging or planting parasites is worrying you, remember that you are trying to create a biological web, not a garden)!

Parasitic trees and shrubs

Some of the ecological benefits of one obligate parasitic plant of Subtropical, Warm Temperate, Gallery, Dry, Dry Gully and Littoral Rainforests (Cherry Ballart *Exocarpos cupressiformis*) include:

- Fruit used by a wide range of rainforest birds who bring other rainforest seed onto your restoration site and disperse it (European Starling, Blackbird, Noisy Friarbird, Mistletoebird, Australian Raven, Grey Currawong, Olive-backed Oriole, Grey Butcherbird, Black-faced Cuckoo-shrike, Satin Bowerbird, Yellow-faced Honeyeater, Lewins Honeyeater, Red Wattle Bird, Silver-eye, Rainbow Lorikeet and Musk Lorikeet)
- Foliage browsed by Black Wallabies who bring other rainforest seed onto your restoration site (Shrubby Fireweed *Senecio minimus* and Forest Nightshade *Solanum prinophyllum*, Seaberry Saltbush *Rhagodia candolleana*, Tree Violet *Melicytus dentatus* s.l. and probably others).

Cherry Ballart can be readily propagated in the nursery (see Propagation Manual) and potted up with an appropriate wattle host (for the rainforest floristic community) and planted out into your restoration site (Propagation Manual: Opener). Be aware, though, that they can shorten the life-span of longer lived trees in some circumstances (such as killing eucalypts over a 30-40 year period) if established too close to them, whereas their impact on shorter-lived wattles is negligible (Propagation Manual: Opener).

Table S11. The distribution of some epiphytes and lithophytes by rainforest *EVC* (and their hosts or substrate).

Moisture gradient	Species	Rainforest EVC	Hosts and or substrate	Notes
Driest	Chinese Brake *Pteris vittata*	***DRf***	Limestone only	Lithophyte (on rock) only. Not tried
	Rock Felt-fern *Pyrrosia rupestris*	DRf, ***DGRf***, ***WTRf***, ***LRf***, ***GRf***	Blackwood *Acacia melanoxylon* and Lilly Pilly *Syzygium smithii* rhyolite, metasediments	Successfully established on Coast Banksia and Blackwood in Warm Temperate Rainforest
	Port Jackson Fig *Ficus rubiginosa*	***STRf***, DRf, LRf	Eucalypts, sandstone, rhyolite, granitoids	Easy to establish on rock with small seedlings and a bit of mulch and some follow-up watering
	Common Spleenwort *Asplenium trichomanes*	DRf, LRf	Limestone only	Lithophyte (on rock) only. Not tried
	Rock Orchid *Dendrobium speciosum*	DRf, LRf	Lithophyte: metasediments, rhyolite	Easy to grow in a crevice with a little leaf litter; no water
Intermediate	Prickly Rasp Fern *Doodia aspera*	LRf	Limestone only	Not tried
	Bird Nest Fern Asplenium australasicum	STRf, LRf	Swamp Oak *Casuarina glauca*, Giant Stinging Tree *Dendrochnide excelsa*, lithophyte	Not tried, but adaptable and widely grown
	Gypsy Fern *Ctenopteris heterophylla*	WTRf, GRf	Kanooka *Tristaniopsis laurina*	Not tried
	Common Filmy-fern *Hymenophyllum cupressiforme*	WTRf, GRf	Blackwood *Acacia melanoxylon*, Kanooka *Tristaniopsis laurina*, lithophyte	Not tried
	Elkhorn *Platycerium bifurcatum*	STRf, LRf	Swamp Oak *Casuarina glauca*, Figs *Ficus* spp., lithophyte: rhyolite	Not tried, but adaptable and widely grown
	Kangaroo Fern *Microsorum pustulatum*	GRf, WTRf, LRf	Lilly Pilly *Syzygium smithii*, Kanooka *Tristaniopsis laurina*, Coast Banksia *B. integrifolia*	Successfully established on Boobialla and in soil on 15-year-old restoration sites
Wettest	Weeping Spleenwort *Asplenium flaccidum*	WTRf, ***CTRf***	Eastern Leatherwood *Eucryphia moorei,* Lilly Pilly *Syzygium smithii*	Not tried
	Ironbark Orchid *Dockrilla aemulum*	GDRf	Grey Myrtle *Backhousia myrtifolia*	
	Dagger Orchid Dockrilla *pugioniforme*	CTRf	Sassafras *Doryphora sassafras*	
	Shiny Filmy-fern *H. flabellatum*	WTRf	Tree-ferns and the bases of trees	Not tried
	Narrow Filmy-fern *H. rarum*	WTRf	Tree-ferns and rocks	Not tried
	Veined Bristle-fern *Polyphlebium venosum*	WTRf	Soft Tree-fern	Not tried
	Jungle Bristle-fern *Macroglena caudata*	WTRf	Soft Tree-fern	Not tried
	Mother Spleenwort *Asplenium bulbiferum*	WTRf, CTRf	Tree-ferns	Not tried
	Fork Ferns *Tmesipteris* spp. (*obliqua, parva, ovata*)	WTRf	Soft Tree-fern , Rough Tree-fern	Not tried
	Fieldia *Fieldia australis*	WTRf, CTRf	Soft Tree-fern, Rough Tree-fern	Not tried
	Butterfly Orchid *Sarcochilus australis*	WTRf	Sweet Pittosporum *Pittosporum undulatum*, Prickly Currant-bush *Coprosma quadrifida*	Not tried
	Orange Blossom Orchid *S. falcatus*	WTRf	Blackwood *Acacia melanoxylon*	Not tried

THE HARDIER EPIPHYTES CAN BE ESTABLISHED ARTIFICIALLY WITHIN THE FIRST 15 YEARS

Figure S152. Arandene Gully, Lakes Entrance Victoria. Fragrant Fern *Microsorum scandens*, is highly moisture dependent and can establish on small hosts when atmospheric humidity is high. This need for high humidity can be circumvented to some degree by planting it in the soil in deep shade up against a host that it can climb. It will climb when sub-canopy moisture levels permit. This species is widely poached from accessible sites.

Figure S153. Golf Links Road, Lakes Entrance Victoria. Photographed in 2005, this plant of Kangaroo Fern *Microsorum pustulatum* was established on Common Boobialla *Myoporum insulare* in moderate shade by the author. This species is much more exposure-tolerant than Fragrant Fern. This epiphytes establishment was achieved during the drought in 2003 at a 15-year-old restoration site at Kinkuna in Lakes Entrance. Note that 3 years after planting, it is already setting spore. Other successfully established epiphytes at this site include Rock Felt-fern *Pyrrosia rupestris*, the parasitic vine Rusty Dodder-laurel *Cassytha phaeolasia*[1], and Coast Mistletoe *Muellerina celastroides*. Two other mistletoe species, Box Mistletoe *Amyema miquelii* and Creeping Mistletoe *Muellerina eucalyptoides,* had also established on Blackwood *A. melanoxylon* and were, at this time, producing fruit.

It may come to you as a surprise that these species should be encouraged on your restoration site at all. There are several reasons. Firstly, they are a part of the natural biodiversity of such sites. Secondly, although they are parasites, they rarely cause the death of the host and the ecological benefits of having them on your site are substantial. All of the parasites that occur in rainforest within the region are fruit bearing and some, particularly mistletoes, provide abundant nectar in the depths of winter (e.g. Variable Mistletoe *Amyema congener*, Drooping Mistletoe *A. pendula* and Grey Mistletoe *A. quandang*).

Mistletoes and dodder laurels

Both of these plant groups are aerial parasites that rely on the host plant for water and minerals. They do this by having modified roots called haustoria (suckers) that penetrate the bark of the host (e.g. Propagation Manual: Opener; Additional Reading: Figure AR33) to gain access to the resources that they require to survive.

There are 90 species of mistletoe in Australia, with 71 endemic (NHT 2001); in our region there are 10 species associated with rainforests (Appendix S6: Worksheet: Mistletoe hosts). Mistletoes do not necessarily kill trees: in low densities they have few deleterious effects on their hosts. Hosts have many defences against mistletoe colonisation and persistence (but this may be compromised when the tree is stressed) and there is some evidence that unhealthy trees are prone to mistletoe colonisation (NHT 2001). Even when mistletoe loads are high, this process of acquiring mistletoe colonies takes many years and, from an ecological perspective, if the host has successfully reproduced, then the cause of death is immaterial to the survival of the host species on the site. In the intact landscape and in rainforests, the ecological values of mistletoes far outweigh any problems that they may cause to individual trees. Their impact in fragmented landscapes may be different (but the solution is also in our hands: Additional Reading: Restoration, mistletoe planting and mistletoe colonisation).

[1] Those parasitic plants that begin life in the soil (Dodder-laurels *Cassytha* spp., Cherry Ballart *Exocarpos cupressiformis* and Blunt-leaved Sandalwood *Santalum obtusifolium*) can be propagated from seed in the nursery, and the seedlings placed in a pot with a suitable host and within the year both can be planted out on to the restoration site (Propagation Manual). Mistletoes regularly colonise restoration sites (Figures FR62 to FR65), but If mistletoes fail to do so on your site and it is in a fragmented landscape (Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes) you can sow them directly onto the host in the field (Figures FR66 to FR68) at your restoration site (Additional Reading: Restoration, mistletoe planting and mistletoe colonisation).

MOSSES ARE SOMETIMES USED FOR INSULATION AND THE STRUCTURE OF NESTS

Figure S154. Cann River Bushland Reserve, Cann River Victoria. Golden Weft-moss *Thuidiopsis furfurosa* (left) is common in damper habitats ranging into rainforest in south-eastern Australia (Meagher and Furhrer 2003) in the light shade cast by secondary species in gaps. This example is found beneath Forest Burgan *Kunzea* sp. (Upright form) which is a secondary species in *Alluvial Terraces* Warm Temperate Rainforest at this site. Nearby, this beautiful nest of Bassian Thrush *Zoothera lunulata* (right) is constructed largely from Golden Weft-moss. Honeyeaters seem to favour the thinner and more wiry *Thuidopsis sparsa*, which is common on a Framework Restoration Method site at Maringa Creek, where it was incorporated into a nest 5 years after works began.

Figure S155. Tributary of Boggy Creek (left) and Reedy Arm Number 2 (right): both in Lake Tyers Forest Park, Victoria. Two other examples of rainforest mosses being used for nest construction. The moss used in the Black-faced Monarch's nest (left) is *Wyemouthia mollis* and only occurs in the humid areas of rainforest (Meagher and Furhrer 2003), in conditions only maintained by an intact, closed and mature rainforest canopy. These latter requirements for its nest-making material, limit Black-faced Monarch's *Monarchia melanopis* breeding habitat to mature rainforests. Brown Gerygone *G. mouki* (right), which is in the very early stages of construction of its pendulous nest, is using also using *Weymouthia mollis* (but to a much lesser degree than the Black-faced Monarch). The other moss, which comprises the bulk of the nest, is suspected to be *Thuidium cymbifolium*: a rainforest most of eastern Victoria and New South Wales (Meagher and Furhrer 2003). Photographs of the monarch and gerygone: Rohan Bilney.

As a food source, mistletoes are one of the few Australian plant groups to be pollinated and dispersed by animals: their fruit is high in protein, carbohydrates and lipids and are often produced at a time when few other such resources are available in the district (NHT 2001). The leaves are very nutritious, being high in nitrogen, phosphorus and trace elements. The foliage is browsed by Greater Gliders *Petauroides volans,* Sugar Gliders *Petaurus breviceps,* Common Ringtail Possums *Pseudocheirus pereginus*, Common Brushtail Possums *Trichososurus vulpechula* (NHT 2001) and a variety of butterfly larvae: Jezabels *Delias* spp. and Azures Ogyris spp. (Braby 2000)]. During drought and seasonal scarcity, these nectar, fruit and foliage resources are especially important to a range of Australian birds and mammals (NHT 2001). With the exception of areas severely fragmented by clearing, mistletoes are kept in balance by this herbivory and fires (NHT 2001).

FLOODS, MUDS AND MOSSES

Figure S156. Site 70f Marlo Road, Snowy River Victoria. Mud deposited in shade during the June 2007 Snowy River floods on our rainforest restoration site has remained moist for 3 months (at the time of the photograph). As can be seen, the first filamentous stage of the moss has coloured the mud green (across the centre of the photograph), mature mosses have grown and fern establishment begins (blue circle) (and germination follows: Appendix S5; Figures 10.2-10.4).

Mistletoes in general are very important ecologically and are keystone species because they have a disproportionately large impact on some faunal assemblages (Watson 2001; Watson 2002) particularly birds and arboreal mammals (NHT 2001). This is primarily because they flower and fruit for much of the year, and the presence of only two species is enough to provide these resources all year round. This is well illustrated by a rainforest site on the Cann River, Victoria (Appendix S4: Worksheet: Honeyeaters) where: flowering of one species and fruiting of two species occurs for 8 months (April-November); flowering and fruiting of both species occurs in 1 month (December); flowering of both species occurs for 2 months (January-February) and flowering and fruiting of one species occurs for 1 month (March). Studies in woodlands have shown that bird abundance and diversity is related to the level of mistletoe present in woodlands (Watson 2002) and that dispersal rates are linked to larger mistletoe colonies (Ward and Paton 2007).

A study of Box Mistletoe *Amyema miquelii* in eucalypt woodland (a species also found in rainforest in south-eastern Australia) showed higher Mistletoe Bird *Dicaeum hirundinaceum* populations occur around such colonies and a propensity to produce a 'contagious distribution'; in other words, more mistletoe are more often dispersed nearer larger parent colonies of the plant (Ward and Paton 2007). In East Gippsland, this species is in fruit locally when the bird is breeding. This does not, however, preclude rarer large scale dispersal distances with gut retention times, suggesting between 13 and 255 seeds could be dispersed over 500m (Ward and Paton 2007). The figures vary according to whether there was one only mistletoe per tree or up to 20 (Ward and Paton 2007). So what does all that mean? Well if there are no mistletoes within 500m (and you want some on your site), it's best to plant them! Guidelines from our successful mistletoe plantings are provided in Additional Reading: Restoration, mistletoe planting and mistletoe colonisation.

Mistletoes support greater animal diversity by providing nectar, fruit and palatable foliage to browsers such as insects and possums. Similar observations have been made locally in the rainforests of south-eastern Australia. Because mistletoes are destroyed by fire, rainforest habitat provides them with a refuge for the recolonisation of the wider landscape following fire. In East Gippsland, this conservation of mistletoe in rainforest during fire has been noted for plants found on both eucalypts and wattles and provides important and long-lasting resources to a wide range of birds ranging from the Mistletoebird itself, through Silvereyes and honeyeaters. The last two are fundamental to the dispersal of rainforest fruit-bearing species in south-eastern Australia. Without these fire refuges, and the mistletoes that they harbour during times of such severe landscape stress, both the future of these bird ***guilds*** and rainforest regeneration they promulgate would be in doubt.

Dodder laurels in rainforest (of which there are several species) occur on many species (Table S12), whereas. mistletoes display a remarkable degree of host specificity in south-eastern Australia:

- *Amyema cambadgii* grows on River Oak *Casuarina cunninghamii* and Swamp Oak *C. glauca*
- Grey Mistletoe *Amyema quandang* is a species that is restricted to a single genus: Acacias (7 species of which occur in Victorian rainforests)
- Box Mistletoe *Amyema miquelii* and Creeping Mistletoe *Muellerina eucalyptoides* grow on both wattles and eucalypts
- In the region covered by this work, Coast Mistletoe *Muellerina celastroides* prefers Coast Banksia *B. integrifolia* (Figure S157) but other hosts include rainforest trees such as Yellowwood *Acronychia oblongifolia,* Sassafrass *Doryphora sassafras*, Lilly Pilly *Syzygium smithii*, and many other species (Appendix S6: worksheet: Mistletoe hosts). There is an interesting relationship with another Littoral Rainforest species, Sea Box *Alyxia buxifolia*, whereby the Mistletoebird eats its fruit, which is in season at the same time as the fruit of the Coast Mistletoe. Coast Mistletoe is common on Sea Box. Mistletoes provide abundant resources to fauna including the butterflies illustrated in Figure S158, Figure S159 and Figures AS9-1 to AS9-3
- Others such as Variable Mistletoe *Amyema congener* do not (as a rule) occur on eucalypts, but grow on wattles, sheoaks, rainforest trees such as Southern Kurrajong (Blackfellow's Hemp) *Commersonia rossii* and Lilly Pilly *Syzygium smithii* as well on other mistletoes in the family Loranthaceae such as Drooping Mistletoe *Amyema pendula* (Figure S160)
- Jointed Mistletoe *Korthalsella rubra* is restricted to rainforest tree hosts such as Yellowwood *Acronychia oblongifolia* and Lilly Pilly *Syzygium smithii*
- Even the root parasite Cherry Ballart *Exocarpos cupressiformis* has mistletoes (Drooping Mistletoe *A. pendula* and Creeping Mistletoe *Muellerina eucalyptoides*)
- One highly specialised Golden Mistletoe *Notothixos subaureus* only grows on other mistletoes.

The dense habit of mistletoes is also a boon for nesting birds, with many species using them for this purpose. Some birds of rainforest in south-eastern Australia recorded as nesting in mistletoe include: Satin Bowerbirds *Ptilonorhynchus violaceous*, White-faced Heron *Egretta novaehollandiae*, Brown Falcon *Falco berigora*, Red Wattlebird *Anthochaera carunculata*, Noisy Friarbird *Philemon corniculatus*, Grey Shrike-thrush *Colluricincla harmonica*, Grey Butcherbird *Cracticus torquatus*, Pied Currawong *Strepera graculina* and Scarlet Honeyeater *Myzomela sanguinolenta* (Watson 2002, Pizzey and Knight 2003 and Frith 1979). The nest shown in Figures S161, Figure S162 and Figure S163 in Coast Mistletoe *Muellerina celastroides* (a species of Littoral Rainforest) is that of a Little Wattlebird *Anthochaera chrysoptera*, so perhaps these observations hold true for these rainforests as well.

Local observations also show the importance of mistletoe clumps as roosting sites for birds. On one farmland restoration site in East Gippsland, large family groups of magpies use such clumps for secure overnight shelter. As this species is very important for the control of insect pests in adjacent farmland, mistletoes take on a whole new role in farm ecology and pest management.

Mistletoes also play a major role in the development of hollows in eucalypts in woodland (Watson 2002) – a feature also regularly noted in the rainforests of south-eastern Australia. This occurs when branches (particularly large ones) hosting mistletoe die. The dead wood is then colonised by fungi and termites and a new hollow develops. Hollows are very important to a number of animal guilds that use them for nesting and or shelter. These animals include mammals, birds, reptiles, amphibians and insects. Many of these species control serious agricultural insect pests in rural landscapes.

Table S12. Mistletoes and dodders of south-eastern Australian rainforests: initial and final hosts (see also Appendix S6: worksheet: Mistletoe hosts).

Mistletoe and rainforest type	Initial hosts (planting)	Final hosts (natural spread)*
Needle-leaf Mistletoe *Amyema cambagei. GRf*.	See Final hosts	Emergent species over rainforest: River Oak *Allocasuarina cunninghamii* and Swamp Oak *C. glauca*.
Variable Mistletoe *Amyema congener. STRf*, *WTRf*, *LRf*.	Black She-oak *Allocasuarina littoralis*, Black Wattle *Acacia mearnsii*, Southern Brush Kurrajong *Commersonia rossii*	Rainforest species: Maidens Wattle *Acacia maidenii*, Common Silkpod *Parsonsia straminea*, Lilly Pilly *Syzygium smithii* and Drooping Mistletoe *Amyema pendula*
Box Mistletoe *Amyema miquelii.* LRf. (Figures S165, S166)	Silver Wattle *Acacia dealbata*,	Rainforest species: Blackwood *A. melanoxylon,* Blue Box *Eucalyptus baueriana*, Coast Grey Box *E. bosistoana*, <u>Red Ironbark</u> <u>*E. tricarpa*</u>, <u>Eurabbie</u> <u>*E. globulus* ssp. *bicostata*</u>.
Drooping Mistletoe *Amyema pendula.* WTRf, LRf.	Black Wattle *A. mearnsii*	Rainforest species: Limestone Blue Wattle *Acacia caerulescens*, *Blackwood A. melanoxylon,* <u>Blue Box</u> <u>E. baueriana</u>, <u>Eurabbie</u> <u>*E. globulus* ssp. *bicostata*</u>, <u>Mountain Grey Gum</u> <u>*E. cypellocarpa*</u>, <u>River Peppermint</u> <u>*E. elata*</u>, <u>Messmate</u> <u>*E. obliqua*</u>, <u>Manna Gum</u> <u>*E. viminalis*</u>
Grey Mistletoe *Amyema quandang.* WTRf, GRf, *DRf* (to date: Buchan-Murrindal, Tambo rivers only).	Silver Wattle *Acacia dealbata* and Black Wattle *A. mearnsii*.	Rainforest species: Limestone Blue Wattle *Acacia caerulescens*, Lightwood *Acacia implexa*, Blackwood *Acacia melanoxylon*. Less common species of rainforest: Hickory Wattle *A. falciformis*, Red Wattle *A. silvestris*
Rusty Dodder-laurel *Cassytha phaeolasia.* WTRf, GRf, LRf.	Sallow Wattle *Acacia longifolia,* Black Wattle *A. mearnsii*, Coast Wattle *A. longifolia* ssp. *sophorae,* Hops Goodenia *Goodenia ovata*	Rainforest species: Limestone Blue Wattle *Acacia caerulescens*, Black Wattle *A. mearnsii*, Black Blackwood *A. melanoxylon,* Coast Sallow Wattle *A. longifolia* ssp*. sophorae,* Staff Climber *Celastrus australis*, Giant Hop-bush *Dodonaea viscosa*, Wombat Berry *Eustrephus latifolius,* Cherry Ballart *Exocarpos cupressiformis,* Scrambling Lily *Geitonoplesium cymosum,* Coast Beard-heath *Leucopogon parviflorus,* Swamp Paperbark *Melaleuca ericifolia,* Tree Violet *Melicytus dentatus,* Tree Broom-heath *Monotoca elliptica*, Common Boobialla *Myoporum insulare,* Large Mock Olive *Notelaea venosa,* Sticky Daisy-bush *Olearia viscosa,* Sweet Pittosporum *P. undulatum,* Hazel Pomaderris *P. aspera,* Seaberry Saltbush *Rhagodia candolleana,* Kanooka *Tristaniopsis laurina.* Occasional species of rainforest: Swamp Paperbark *Melaleuca ericifolia.*
Long-flower Mistletoe *Dendrophthoë vitellina.* WTRf.	Rough-barked Apple *Angophora floribunda,* Sweet Bursaria *B. spinosa*	Rainforest species: Lilly Pilly *Syzygium smithii.*
Jointed Mistletoe *Korthalsella rubra*. STRf, WTRf.	Lilly Pilly *Syzygium smithii*	Rainforest species: Lilly Pilly *Syzygium smithii.*
Coast Mistletoe *Muellerina celastroides.* LRf.	Coast Banksia *Banksia integrifolia,*	Rainforest species: Blackwood *Acacia melanoxylon*, Sea Box *Alyxia buxifolia*, Prickly Currant-bush *Coprosma quadrifida*, Sassafras *Doryphora sassafras*, Coast Beard-heath *Leucopogon parviflorus,* Hazel Pomaderris *P. aspera,* Tree Broom-heath *Monotoca elliptica* and Lilly Pilly *Syzygium smithii.*
Creeping Mistletoe *Muellerina eucalyptoides.* WTRf.	Black Wattle *A. mearnsii*, Tree Hakea *H. eriantha*	Rainforest species: Maidens Wattle *Acacia maidenii*, Blackwood *A. melanoxylon*, Sea Box *Alyxia buxifolia*, <u>Blue Box</u> <u>*E. baueriana*</u>, Coast Grey Box *E. bosistoana*, Southern Mahogany *Eucalyptus botryoides*, Mountain Grey Gum *E. cypellocarpa*, <u>Eurabbie</u> <u>*E. globulus* ssp. *bicostata*</u>, <u>Forest Red Gum</u> <u>*E. tereticornis*</u>, Woolybutt *E. longifolia*.
Golden Mistletoe *Notothixos subaureus.* WTRf.	Needle-leaf Mistletoe *Amyema cambadgii*	Rainforest species: Mistletoe *Amyema cambadgii,* Box Mistletoe *A. miquelii*

*<u>Underlined host species</u> are noted locally to respond to mistletoes with limb death that can lead to hollow formation.
See Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes for details on sowing

MISTLETOES AND BUTTERFLIES GO HAND IN GLOVE

Figure S157. Eastern Beach, Lakes Entrance Victoria. Coast Mistletoe *Muellerina celastroides* is a species frequently found in Littoral Rainforests along the eastern seaboard including those of south-eastern Australia as well as in other rainforests further north (Harden 2002). This species provides nectar and fruit to many rainforest birds as well as forage for some our most beautiful rainforest butterflies (Figures S158, S159).

Figure S158. Black Jezabel *Delias nigrina*'s (left) larvae feed on the leaves of Coast Mistletoe *Muellerina celastroides* (Figure S157) and adults supp on the nectar of Coast Banksia flowers (Figure S78). It is common in the Littoral Rainforests of southern New South Wales and is recorded by Braby (2000) as occurring as far south as Cann River, Victoria. The author discovered this species breeding on Coast Mistletoe in Littoral Rainforest at Lakes Entrance in 2008 (Figures AS9-1 to AS9-4). Photo: <www.HelenSchwenkebutterflyencounters.com.au>

Figure S159. Though not recorded by Braby (2004) as a food plant, Imperial Jezabels *Delias harpalyce* is thought to feed on Coast Mistletoe in Victorian Littoral Rainforests. It uses other mistletoes of rainforest such as Box Mistletoe *Amyema miquelii*, Variable Mistletoe *A. congener*, Drooping Mistletoe *A. pendula*, Creeping Mistletoe *Muellerina eucalyptoides* and occasionally Grey Mistletoe *A. quandang*. Photo: M. and P. Coupar. Source: Museum of Victoria.

SOME MISTLETOES LIVE ON OTHER MISTLETOES

Figure S160. Bermagui-Tathra Road, Tanja New South Wales. Variable Mistletoe *Amyema congener* (red arrow) is growing on Drooping Mistletoe *A. pendula* (green arrow) that is in turn growing on Black Wattle *Acacia mearnsii* providing nectar and fruit throughout the year. Their leaves feed a range of beautiful summer butterflies such as Scarlet Jezabel *Delias harpalyce.*

A few quick local observations regarding the ecological benefits of some of the region's mistletoes suggest a significant local role here as well. Those observed to date (see Additional Reading: *Mistletoes make rainforest in fragmented landscapes*) include:

Drooping Mistletoe *Amyema pendula*:

- Provide browse for Brush-tail Possums who disperse other rainforest seed onto your restoration site. Examples recorded to date include: Common Apple-berry *Billardiera mutabilis,* Common Boobialla *Myoporum insulare* and Kangaroo Apple *Solanum aviculare*
- Nectar used by a range of generalist birds, some of which are also rainforest birds (Red Wattle-bird *Anthochaera carunculata*, Brush Wattlebird *Anthochaera chrysoptera*, Eastern Spinebill *Acanthorhynchus tenuirostris*, New Holland Honeyeater *Phylidonyris novaehollandiae* and Yellow-faced Honeyeater *Lychenostomus chrysops*). Some of these species also bring rainforest seed onto your restoration site and disperse it. For example, Red Wattlebirds have been recorded locally to disperse six rainforest plants, while Yellow-faced Honeyeaters are known to disperse ten species: a total of 13 plants between them (Appendix S8).

Coast Mistletoe *Muellerina celastroides* and Creeping Mistletoe *Muellerina eucalyptoides*:

- Nectar used by a wide range of generalist honeyeaters some of which are likely to bring other rainforest seed onto your restoration site and disperse it;
- General role in rainforest colonisation and recovery: Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes

MISTLETOES MAKE EXCELLENT NEST CAMOUFLAGE AND IMPROVE BREEDING SUCCESS

Figure S161. Entrance Walk Cunninghame Arm Lakes Entrance, Victoria. Because emergent species in Littoral Rainforest, such as this Coast Banksia B. *integrifolia*, have sparse canopies, the dense foliage of mistletoe has obvious advantages in terms of nest camouflage and protection from wind: see below.

Figure S162. Entrance Walk, Lakes Entrance Victoria. A closer look: Coast Mistletoe *Muellerina celastroides* can not only provide a safe and secure nest site it is also a source of nectar and fruit to other species as well – can you see any nest yet? No? Well, look at Figure S163.

Figure S163. Entrance Walk, Lakes Entrance Victoria. The nest revealed! This nest of a Brush Wattlebird *Anthochaera chrysoptera* is located in a clump of Coast Mistletoe growing on a young Coast Banksia *B*. *integrifolia*, adjacent to Littoral Rainforest.

Mistletoes are very abundant in riverine ecosystems for two reasons. Firstly, many are able to rapidly colonise wattles, which are abundant along rivers (Blackwood *Acacia melanoxylon*, Black Wattle *A. mearnsii*, Silver Wattle *A*. *dealbata*), either because they are frequently regenerated as a result of flood events. Secondly, the mistletoe colonisation persists because of a lack of fire. As a consequence, higher levels of mistletoe colonisation are restricted to habitats that are not frequently burnt: riparian zones and rainforests being two such areas of the landscape. Consequently, mistletoes are more abundant in old stands of vegetation that includes long-lived wattles such as Blackwood *A*. *melanoxylon* along riparian zones and on large old emergent eucalypts over rainforest, as well as shorter-lived species (Figure S164).

This added layer of resources provided by mistletoes can make rainforests (in all of their successional stages) extremely rich and important habitats for honeyeaters with: 11 species locally recorded using their nectar: Brush Wattlebird, Red Wattlebird, Regent Honeyeater, Scarlet Honeyeater, New Holland Honeyeater, Eastern Spinebill, Crescent Honeyeater, Yellow-faced Honeyeater, Bellbird, Noisy Friarbird and Rainbow Lorikeet (Appendix S8) and one that eats their fruit: Red Wattlebird (Appendix S8). Another 4 species that use rainforests as habitat (Lewins Honeyeater, White-naped Honeyeater and the migratory species Fuscous Honeyeater and Little Friarbird) may also use these mistletoe resources, but to date, they have not been locally recorded as doing so. Apart from their essential role in pollination; honeyeaters are very important on your site for insect control, as they feed on them when nectar is in short supply and when breeding (as there is not much protein in nectar) and their young cannot grow on sugar alone..

Remember, mistletoes are relatively easy to 'plant' on your site. Coast Mistletoe has been successfully sown on Coast Banksia *B. integrifolia.* Given the important ecological role of mistletoes, especially in fragmented landscapes (Additional Reading: Mistletoes and rainforest regeneration: vital in fragmented landscapes), it is probably worthwhile incorporating them into your plantings if required (Appendix S6: Worksheet: Mistletoe hosts). The context for doing so is two-fold: it increases biodiversity (considerably improving nectar and fruit yields for the site and for earlier successional stages: often before other species flower or fruit) and thereby improves the chances of natural regeneration of other fruit-bearing species dispersed by honeyeaters and delivered to your site (Appendix S4: worksheet: Honeyeaters):. The presence of mistletoes is also likely to assist the range of expansion of important rainforest-dependent birds such as the summer migrants: Channel-billed Cuckoos *Scythrops novaehollandiae* and Common Koels *Eudynamys scolopacea* (Appendix S8) that are extending their range southwards to the Gippsland Lakes during this period of climate change. Hence we use the term ***climate change migrants*** for these species in East Gippsland, compared with ***climate change immigrant*** (which to date has only been applied to the southward and altitudinal colonisation of Figbirds in south-eastern Australia).

If you choose to plant mistletoes, it is important to realise that the plants you sow will themselves provide mistletoe seed that will ultimately be transferred to some of the eucalypts or rainforest canopy species in your planting as they mature in 15-30 years time (Table S12). Herein lies an important caveat, where the surrounding vegetation includes: Coast Grey Box *Eucalyptus bosistoana*, Yellow Box *E. melliodora* or Red Box *E. polyanthemos*: do not encourage Box Mistletoe *Amyema miquelii*, unless you are sure that these eucalypts are sufficiently abundant, or young enough to cope with ***secondary colonisation*** from your rainforest plantings. Otherwise, mistletoes appear pretty host (Table S12) and EVC-specific:

- Mistletoe *Amyema cambagdii*: Warm Temperate Rainforest, Gallery Rainforest and Littoral Rainforest
- Mistletoe *Amyema congener*: Subtropical Rainforest and Littoral Rainforest
- Box Mistletoe *Amyema miquelii* (Figures S165, S166): Littoral Rainforest
- Drooping Mistletoe *Amyema pendula*: Warm Temperate Rainforest and Littoral Rainforest
- Grey Mistletoe *Amyema quandang* (Figure S167)*:* Warm Temperate Rainforest, Gallery Rainforest and Dry Rainforest in rain shadow river valleys
- Long-flower Mistletoe *Dendrophthoë vitellina*: Littoral Rainforest
- Jointed Mistletoe *Korthalsella rubra*: Warm Temperate Rainforest and Subtropical Rainforest
- Coast Mistletoe *Muellerina celastroides*: Littoral Rainforest
- Creeping Mistletoe *Muellerina eucalyptoides*: Warm Temperate Rainforest
- Golden Mistletoe *Notothixos subaureus*: Littoral Rainforest.

WATTLES HOST A MULTITUDE OF MISTLETOES SPECIES AND SO PROVIDE NEST SITES AND NECTAR

Figure S164. Left bank Cann River, downstream of the West Cann Bridge Victoria. Black Wattle *Acacia mearnsii* that has collapsed into restored Warm Temperate Rainforest. This remnant tree provided nectar to honeyeaters through its life-long mistletoe complement; a legacy that did not die with the tree but was passed on to others such as the Southern Mahogany *Eucalyptus botryoides* (red arrow). Honeyeaters have flocked to these mistletoes from the remnant across the river and brought with them the seed of fruits that they have consumed there. Under this particular tree, the rainforest species brought onto the site included: Staff Climber *Celastrus australis*, Tree Violet *Melicytus dentatus*, Sweet Pittosporum *P. undulatum* and others. You can see why this wattle is not a species recommended for planting close to fence lines (see Appendix S6: Worksheet: All species; electric fences column).

Dodder Laurels *Cassytha* spp. are also important ecologically, providing fruits for consumption by a range of rainforest birds and provide vine tangles that are feeding sites for specialised bats such as the Golden-tipped Bat *Kerivoula papuensis* and roosting sites for Sooty Owls *Tyto tenebricosa* that like the dense shade that they cast (Chapter S2: Figure S82). These plants germinate in the soil, then twine around nearby vegetation attaching their ***haustoria*** and then ascend into the canopy. Once they have made contact with a host, they become parasitic and their root system withers and dies. These plants can be germinated in the nursery and planted next to an interim host, which is then planted next to the final host (Propagation Manual) to allow for the transfer (Table S12).

MISTLETOES PROVIDE A WEALTH OF RESOURCES

Figure S165. Thorpes Lane, Lakes Entrance Victoria. The beautiful flower of Box Mistletoe *Amyema miquelii* is a font of nectar for a range of honeyeaters where it grows mainly on Coast Grey Box *E. bosistoana* in Littoral Rainforest around the Gippsland Lakes and Warm Temperate Rainforest in the Cann and Genoa River Valleys in Victoria; and in the same EVCs around the Top Lake at Merimbula; the lower reaches of the Bega River and Mogareeka Estuary near Tathra as well as over Gully Dry Rainforest around Cuttagee Inlet and nearby areas and the margins of Dry Rainforest and Subtropical Rainforest in and around the Tilba Tilba district.

Figure S166. Thorpes Lane, Lakes Entrance Victoria. Box Mistletoe *Amyema miquelii* showing a gall, which has been opened and the insect consumed, probably by Gang Gang Cockatoos *Callocephalon fimbriatum*. This species relies on relatively substantial tree hollows, some of whose formation is initiated by mistletoes such as this species. This mistletoe is a prolific fruiting species and attracts many species other than Mistletoe birds (including honeyeaters) that also eat the fruit of other rainforest species and disperse their seed.

Cuckoos

These summer breeding migrants (many of which also reach their edge of range in south-east Australia) use the nests and parenting prowess of other birds to bring up their own young and are therefore said to parasitise their hosts (Appendix S2: worksheet: Rainforest cuckoo hosts). It is a real coup when you can record these species as using your restoration site, and even better when they breed there (Additional Reading: Bird breeding censuses). It is a double bonus really: it means that the host species has found the habitat suitable to set up shop, build a nest and breed; a cuckoo has been attracted to your good restoration efforts, and a summer breeding migrant all the way from northern Australia (or even south-east Asia) has been able to successfully breed in your rainforest – and that is a wonderful achievement (Figure S168).

When it happens and why it happens (phenology)

Introduction

The study of ***phenology*** is easy to do and provides some very important insights into what you are trying to achieve in rainforest restoration and how it all fits together into what is the ecology or 'fabric' of your site. If you revel in the arrival of seasonal cycles, then you are probably already doing phenology (Figure S169) without knowing it! As one local fisherman says: "the paperbarks are flowering: so its time to go bream fishing". Because everything lives in a web of life, we are connected to these cycles. The famous saying "that fish live in trees" is really true: whether it be for shelter (e.g. Blackfish *Gadopsis mamoratus;* Koehn and O'Connor 1990), for food or places to lay eggs (all are connected to the seasons, flowering, fruiting, leaf-fall, and so on).

So, when you restore the obvious, you are reinstating a less obvious fabric that you may not always see. This is what phenology is all about. It basically involves making lists of species (plant and animal) and observing their interactions across the seasons and under different climate regimes. Interactions can include: flowering times and pollination, fruiting times and who eats what. Over time, these records give meaning to your individual restoration actions. For example, planting the unloved Scrub Nettle *Urtica incisa* protects your palatable species, but also provides food for the grubs of the beautiful Australian Admiral Butterfly *Vanessa itea*. So the next time you see one pass by you can say: "I made it possible for that animal to live here" – and there are few greater rewards than that in life. Appendix S9 shows that there are many other rewards like this awaiting the rainforest restoration practitioner.

MISTLETOES: A VITAL ECOLOGICAL COMPONENT IN RAINFOREST ECOLOGY

Figure S167. Buchan, Victoria. Grey Mistletoe *Amyema quandang*: a beautiful species that grows exclusively on wattles (including those that grow in rainforest). Note the four clumps silhouetted in the tree's shadow.

Although such observations can be extremely gratifying, they also help you to plan ahead. For example, by planting Muttonwood *Myrsine howittiana* (if your floristic community species list says that is appropriate) you know you will in the future be supplying summer fruits from November to January (Appendix S10). Not only that, but you will supply food to at least ten species (Appendix S10), including the fledgling young of Pied Currawongs *Strepera graculina*. Pied Currawongs are a major disperser of rainforest fruits in the region and are also the species that is parasitised by the magnificent rainforest Channel-billed Cuckoo *Scythrops novaehollandiae* (a summer breeding migrant). Channel-billed Cuckoos travel all the way from eastern Indonesia and Papua New Guinea to be with us over summer (Pizzey and Knight 2003) (Additional Reading: Avian migration patterns). The cuckoo in turn is a major seed disperser of rainforest plants particularly figs (Barker and Vesjens undated a).

Birds and bees (pollinators)

The process of pollination is really a brilliant partnership. Plants provide something, ranging from apparently free sex with a pretend female wasp as in some orchids, to pollen (full of protein for feeding your babies), to nectar (a major energy source for many insects, birds and mammals). In reality, what the plant gets is much more than it gives away. Pollinators basically provide the bridge between flowers, individual plants and, in the case of Grey-headed Flying Foxes *Pteropus poliocephalus,* the freeway (they travel up to 30km) to cross-pollinate and reproduce via the next generation of plant seed. Pollinators, particularly insects, provide food for many other species including other insects, birds, mammals, fish, reptiles and amphibians. One flowering plant can be a smorgasbord to a huge range of diners (Appendix S8). As the following example illustrates, the study of phenology can connect the plant's need for pollen dispersal directly with your sites biggest and most magnificent predators:

Nectar of Southern Mahogany+rainforest fruits=Grey-headed Flying Foxes and lots of them=Flying Fox colony=food to White-bellied Sea Eagles that may also nest in rainforest.

CUCKOOS BREEDING ARE A SURE SIGN OF RAINFOREST RESTORATION SUCCESS

Figure S168. Goldsmith's Gully, Colquhoun Forest Victoria. This baby Brush Cuckoo *Cacomantis variolosus* has his eye on dinner (left), but it's a bit of a shock to see who is delivering it (right): a very busy and hassled White-browed Scrub-wren *Sericornis frontalis*. The rainforest restoration success here is that one rainforest bird is being used by another (a summer breeding migrant from Asia) to complete its breeding cycle. Although several Rainforest Restoration Methods (including Natural Regeneration and the Clumped Mixed Canopy) are being used at this site, it also contains a large natural rainforest remnant. Brush Cuckoos have turned up in 5-year-old Framework Restoration sites (Appendix 1.1: Maringa Ck bird breeding census) and the closely related Fantail Cuckoo *C. flabelliformis* first appeared in Maximum Diversity Restoration of Warm Temperate Rainforest on the Snowy River after 6 years. Photos: Les Goldsmith.

Phenology can also be used to understand your rainforest restoration site in other ways. Take the guild of ten honeyeaters that are regularly recorded using rainforest in south-eastern Australia. Honeyeaters live on nectar and, as a consequence, do a lot of important pollination. But when nectar is scarce and at breeding time they also consume vast amounts of insects, which help to keep the hoards of biting, chewing and gnawing insects in check on your restoration site. But did you know that honeyeaters also eat fruit?

Based on their diet (Appendix S10), the way these birds species use rainforest can be interpreted and is very interesting (Figure S170). The data suggests several feeding strategies: fruit eaters that supplement their diet with nectar (Lewins Honeyeater, Yellow-faced Honeyeater, Red Wattlebird and Brush Wattlebird); generalists that use both fruit and nectar (New Holland Honeyeater, Crescent Honeyeater, Eastern Spinebill and Little Friarbird); and specialised nectar eaters (Scarlet Honeyeaters).

SPRING IS HERE: THE AIR IS THRUMMING WITH CICADAS AND ITS TIME FOR BLACK WATTLE TO FLOWER…

Figure S169. Goldsmith's Gully, Colquhoun Forest Victoria. The emergence (top left) of Green Grocer/Yellow Monday Cicadas *Cyclochila australasiae* (top right and bottom, respectively) after 7 years underground on warm nights after rain (Australian Museum) happens as regular as clockwork in East Gippsland. Their frenetic activity lasts between late October and mid-January, calling any hour of the day and night provided conditions are right (21-29^{o}C). The appearance of this species marks a turning point in the seasons. But what other things come with these obvious and noisy seasonal markers: higher temperatures, higher humidity and the region's first spring-time thunderstorms. It is a time of plenty, and many plants begin their flowering and fruiting and clouds of insects appear: leading to pollination, seed production and food for the young of many species. Around Lakes Entrance, Australian Ravens are having their young and this timing allows them to feed the nestlings on the newly emerged cicadas (Les Goldsmith pers. comm.). These connections are the essence of phenology: linking seasons with the life cycles of those around you. Understand these and you will see that rainforest restoration is much more than revegetation. These adult cicadas are plentiful 18 years following Framework Restoration at Lakes Entrance (Kinkuna), which means egg-laying took place at least 7 years earlier when the site was only 11 years old. Photos: from Goldsmith's Gully Lakes Entrance by Les Goldsmith.

From this information you can begin to appreciate the different roles of each of the honeyeaters that visit your site. Specifically you can appreciate the joy that comes from getting your first Lewins Honeyeater on your rainforest restoration site: you just know that they are dispersing a host of other rainforest species to your plot whenever they visit because 89% of their diets are rainforest fruits.

But here is the rub. We know so little about our plants and animals, especially at a regional scale. This relatively modest publication, and the studies that lie behind it, can (at last count) add another 34 new nectar use records for this honeyeater guild to those of the August HANZAB. These new records include: Lewins Honeyeater: 2, Brush Wattlebird: 4, Noisy Friarbird: 0, Yellow-faced Honeyeater: 5, New Holland Honeyeater: 6, Red Wattlebird: 3, Eastern Spinebill: 5; Scarlet Honeyeater: 4; Crescent Honeyeater: 3; and Little Friarbird: 2. Similarly, these studies have added a further 33 rainforest fruit dispersal records: Lewins Honeyeater: 5, Brush Wattlebird: 4, Noisy Friarbird: 1, Yellow-faced Honeyeater: 15, New Holland Honeyeater: 0, Red Wattlebird: 7, Eastern Spinebill: 0; Scarlet Honeyeater: 0; Crescent Honeyeater: 2; and Little Friarbird: 0.

By taking the species information gleaned from Higgins and Steele (2001) that generated Figure S170, further useful ecological insights can be gained by dividing the food species into overstorey and understorey plants (Figure S171). This gives a rough guide as to the division of habitat between each of the honeyeaters found on your site and shows that there are two major groupings: those that use both the overstorey and the understorey (Lewins Honeyeater, Little Wattlebird, Noisy Friarbird, Yellow-faced Honeyeater, New Holland Honeyeater, Red Wattlebird, Eastern Spinebill and Little Friarbird) and those that only use the canopy (Crescent Honeyeater and Scarlet Honeyeater). It also explains why it is so hard to see Scarlet Honeyeaters: they are small and live in the canopy, but equally why you are more likely to see the similar sized Eastern Spinebills: because they often forage in the understorey.

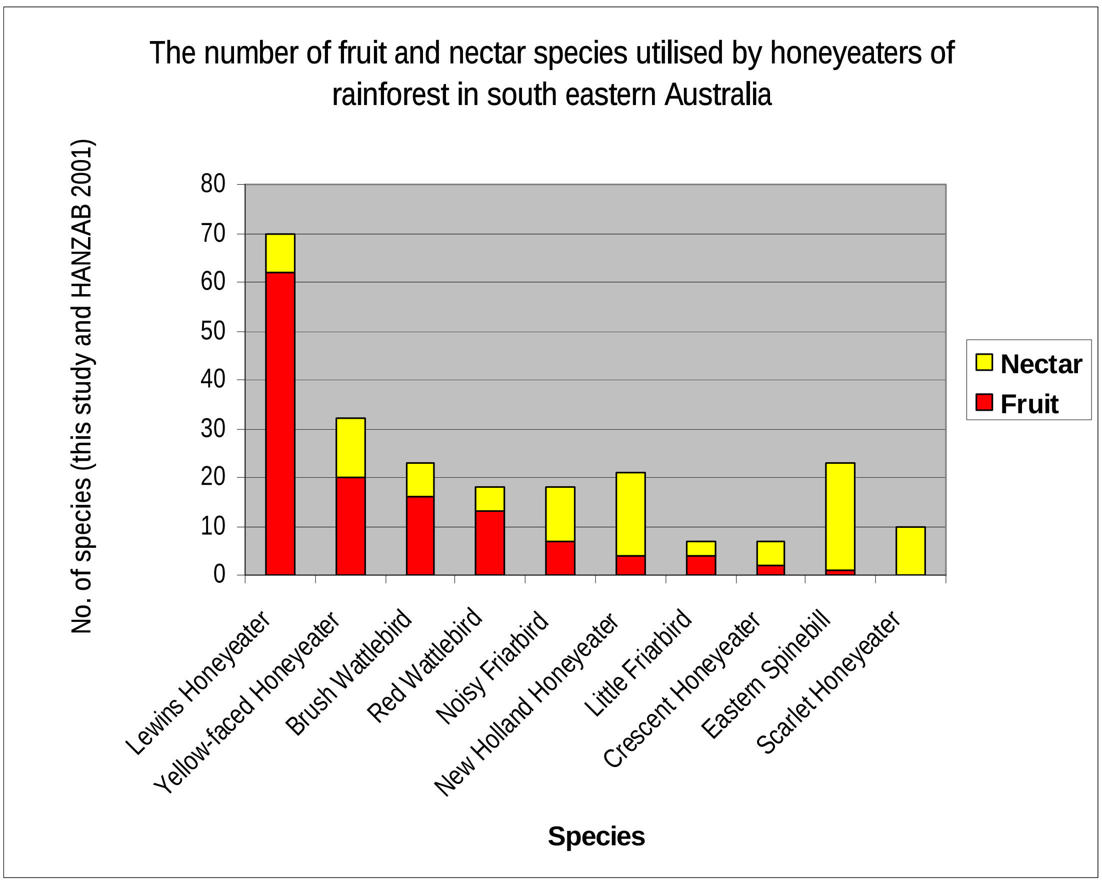

Figure S170. Diet of ten honeyeaters that occur in the rainforests of south-eastern Australia.

Without pollinators (and their other food plants), many honeyeaters would be absent and the species that they help to pollinate would not set seed at all, or do so less effectively. If you think about it, this function is critical to the success of rainforest restoration. Appreciating your pollinators and their life-cycles helps to give your restoration efforts a more profound meaning: a broader picture of the task at hand, as well as providing insight into the intricate interdependencies of the rainforest that one day you hope to reinstate:

- Kangaroo Apples *Solanum aviculare* are fertilised by buzz pollination (Appendix S8). The insect recorded doing this in south-eastern Australia is the Common Carpenter Bee *Amegilla cingulata* <www.brisbaneinsects.com/_wasps/BlueBandBees.htm> (Figure S172). They land on the flower and buzz, showering themselves with pollen and then move off to another plant and repeat the process. Carpenter Bees are particularly attracted to the colour blue that includes flowers <www.fauna.net.gov.au>, one of which is Cockspur flower *Plectranthus parviflorus* (Appendix S8) and these also provide nectar to these bees. The number of bees is dependent on the amount of nectar available – you can see the connection!

- Most daisies are fertilised by butterflies (Lepidoptera) whose long tongues are perfectly suited to probing into the narrow, tightly packed flowers in the heads of daisies whose nectar reservoirs are truly minuscule. Small though these fuel supplies are, they are enough to power the languid flight of myriads of butterflies around your restoration site: a nice bonus. From a pragmatic perspective, more important still is the fact that daisies are fundamental to the ecology of rainforest because they are the early pioneer species that regenerate following disturbance: providing the nursery crops for the moisture dependent and frost and light sensitive mature rainforest plants. Now you can see why knowing your butterflies adds to their beauty (Appendix S9).

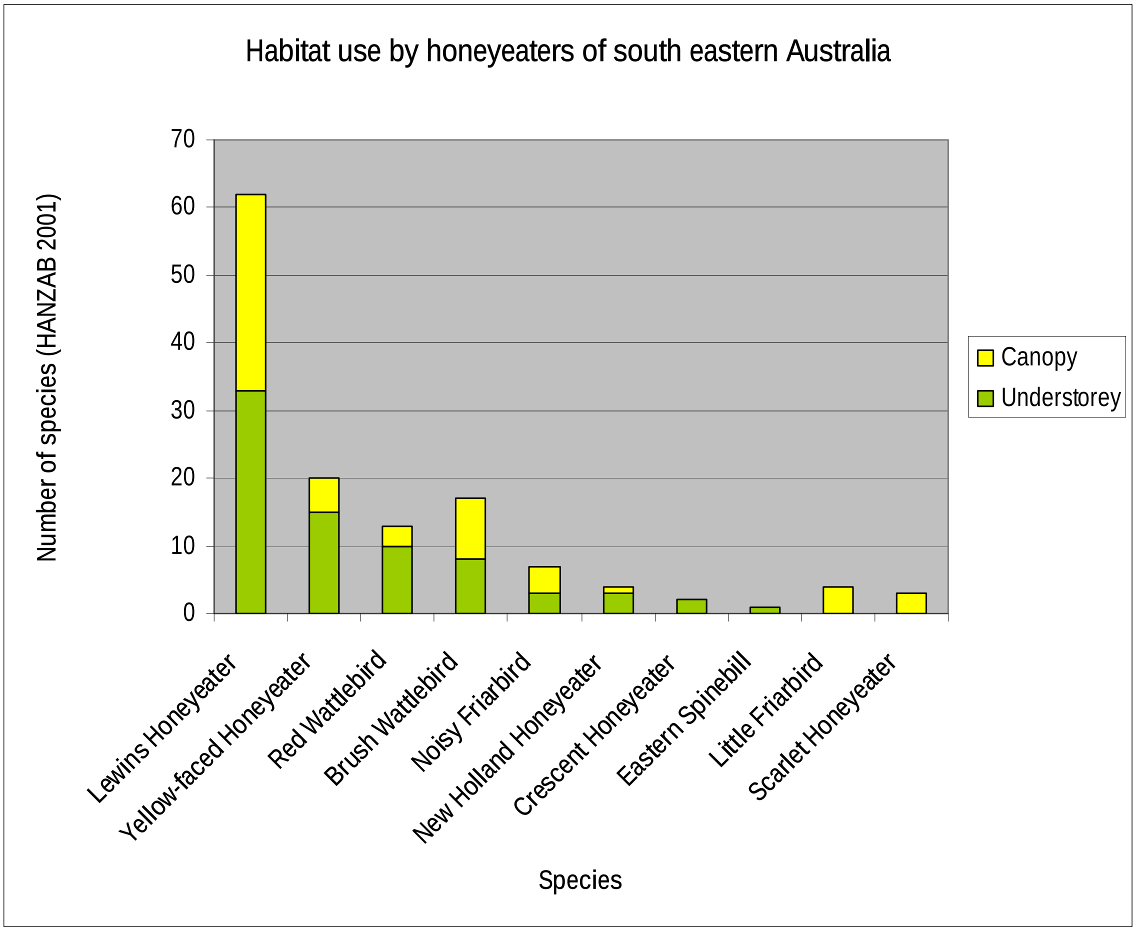

Figure S171. Habitat use by ten honeyeaters that occur in the rainforests of south-eastern Australia.

Butterflies also perform other important duties on your restoration site. Their larvae and those of moths are voracious consumers of foliage: in effect, they keep your site pruned. This may seem a little frustrating, but remember you are not planting a garden. If these grubs and caterpillars were not present and in balance with their food plants, one or other plant would be raging out of control across the landscape and out-competing all of the others: hardly a good recipe for a diverse rainforest restoration site! Such imbalances can be seen with weed species from other countries that do not have these ***biological controls*** to keep them in check.

Butterflies often have other connections with your site. For example, the Imperial Jezebel Butterfly's *Delias harpalyce* larvae feed on the foliage of mistletoes (Figure S173), while the adult butterflies feed off the nectar of the mistletoe flowers. These animals are the harbingers of spring in south-eastern Australia, bringing the promise of warmer weather and summer sea breezes. During hotter weather, flight activity ceases and the adults congregate in cool moist refuges (Braby 2004) such as those offered by rainforest. Another amazing interaction occurs between wattles, Imperial Blue Butterflies *Jalmenus evagorus*, ants and other predators (Figure S174).

NATIVE BEE POLLINATOR

Figure S172. Blue-banded Bee *Amegilla cingulata* is a common native bee of lowland rainforests in south-eastern Australia where it fertilises many blue-flowered plants through buzz-pollination.
Photo: <www.brisbaneinsects.com/_wasps/BlueBandBees.htm>

Consider the following extract from an article in the Australian Geographic Yearbook by Kitching (2005):

Sweet Liaisons: Imperial Blue Butterflies

Predators: The main predators of this species are large mud wasps, bulldog ants, spiders and bloodsucking bugs as well as parasitic wasps that lay their eggs in the butterfly's eggs, grubs and pupae. Where the protector-ants of the genus *Iridomyrmex* (Braby 2004) are operating 70-95% of the caterpillars survive to become pupae, and of these 90% emerged as adult butterflies. If however, the protector-ants are removed 50-100% are of the butterfly's progeny are eaten or parasitised. Of those that make it to the pupal stage 90% were attacked and killed.

Ecological web and the protector ants:

The ants obtain sugary secretions from a large single gland on the head of the caterpillar and four amino-acid producing glands. Both ants and butterflies are inactive over winter, emerging in spring. They find each other by means of the right food plant (a wattle) close to the nest of the right ants. At this point the butterfly relies on a combination of signals including the ants themselves, a treehopper that secretes a sugary substance as a waste that attracts the protector ants. The hoppers are active before the butterflies and consequently the latter can find the ants when looking for sites to lay their eggs where they will get protection. The butterflies are also attracted to the remains of the previous year's pupae cases (Figure S174).

MISTLETOE: FOOD FOR ALL	BUTTERFLIES, ANTS AND WATTLES
	
Figure S173. Gully 1 Maringa Creek Nyerimilang Heritage Park, Victoria. Imperial Jezebel Butterfly *Delias harpalyce* larvae eat mistletoes helping to keep them in check. But all is kept in balance, because the butterflies feed on mistletoe nectar and thereby fertilise its flowers and produce seed for its young – very neat!	Figure S174. Gully 1 Maringa Creek Nyerimilang Heritage Park, Victoria. Imperial Blue Butterflies *Jalmenus evagorus* have protector-ants, which offer the service of protection of the adults, larvae and pupae in exchange for honeydew and amino acids secreted by the butterfly's grubs. These butterflies suffer significant losses to predators if the ants are not there to protect them at every stage. The butterflies seek out wattles that host populations of the protector ants.

When does it fruit and who eats what?
Rainforests are particularly rich in fruiting species and these can be rich in carbohydrates and vitamins (e.g. Lilly Pilly *Syzygium smithii*) or oils (e.g. Blue Oliveberry *Elaeocarpus reticulatus*). Plants keep their fruits an unobtrusive green so as to blend in with their foliage until the seed within is mature. Then the plants paint them a startling colour, to advertise that they are ripe and good to eat (Figures S63, S71, S72, S75 and S175). If you want to know who eats what, then collect the droppings of your rainforest animals and send them off to a nursery to get them grown (Figure S176). You do need to know, however, which animal produced the ***scat***, so get a copy of: '*Tracks, Scats and Other Traces*' (Triggs 2004) and get to work.

For the rainforest restorer, the process of animal dispersal of seed (Appendix S10) represents: free plants through natural regeneration; genetic out-crossing (plants from other populations are brought into your remnant); and a deep sense of satisfaction in seeing a wonderful array of animals come onto your restoration site and enjoy the fruits of your labours. It is no small thing that you do in providing food for animals that depend on it as well as ensuring the survival of the plants in your restored rainforest stand. In time, you can see your plants spreading across the district and contributing to the restoration of other sites as well. The distance that fruiting species can be dispersed depends on the size and diversity of the stand, how close it is to the next stand, how connected it is with other stands (by other bush), how fragmented the landscape is and how old the site is. Only short dispersal distances occur for fruiting species in young revegetation (15 years old): in linear stands in a fragmented landscape of around 1km were found for the lower Snowy; however, with better connections, much greater distances (up to 30km) are possible (Chapter S5: Why proximity to existing bush is important).

Fruits come in all shapes and sizes, ranging from the Rose-leaf Bramble *Rubus rosifolius* with its strawberry-sized fruits (Figure S72) to the worm like arils (like an umbilicus) wrapped around bird-dispersed seeds of some specialised wattles. Sunshine Wattle *Acacia terminalis*, which is not a rainforest wattle, produces a seed that has a very small insipidly coloured adornment called a funicle (Figure S177). The seed is explosively shed from the pod on a hot early summer's day. This small funicle is very attractive to ants (but too small to gain the notice of birds) and encourages them to harvest the fallen seeds and take them into their burrows (effectively sowing them), where the funicle is chewed off for food, but the seed is left intact. Such dispersal is only metres from the adult plant and is directionally random.

The other specialised group – let's call them ***rainforest wattles*** (for reasons that will become apparent) – on the other hand, do not explosively expel their seed, but instead open their pods and dangle their seed from the end of a much larger and more colourful aril until a rainforest bird takes it (Figure S178). Rainforest wattle species with arils (and seed) dispersed in this manner include: Blackwood *Acacia melanoxylon*, Coast Sallow Wattle *A. longifolia* ssp.

sophorae, Maidens Wattle *A. maidenii*, and Lightwood *A. implexa*. As a consequence, numerous birds queue up to eat the oil-rich funicle while doing the plant's bidding by dispersing the seed far from the parent plant where, in time, following disturbance, it may germinate. The seed may be displayed for up to 8 months in this manner (Figure S178). If the fruit-dispersing bird is a rainforest species, then it is highly likely it will fly elsewhere in the rainforest or to the next stand and deposit the seed there. Such seed dispersal occurs across hundreds of metres (if not kilometres) and is directional; in other words, the rainforest plant is finding its way to new rainforest habitats through the bird's habitat and feeding preferences (Chapter 3: Cover). This is something ants hunting for the smaller funicles of explosively-expelled wattle seeds, cannot do (Figure S179).

SEED DISPERSAL NEEDS A LITTLE BRIBERY

Figure S175. Lower Bemm River, Victoria. Muttonwood Myrsine howittiana: bountiful in its December fruiting. This abundance causes rainforest birds to flock from far and wide. In this stand, Pied Currawongs *Strepera graculina* (staying on to feed their young before migrating up into the mountains for the rest of summer), Topknot Pigeons *Lopholaimus antarcticus* (that have migrated from New South Wales for the feast) and Lewins Honeyeaters *Meliphaga lewenii* (who are residents in these lowland rainforests year-round) all partook. The other, less obvious, food source for the honeyeaters (red arrows) is provided by one of the honeydewers in this case scale insects (Appendix S6: worksheet: Honeydewers) that secrete honeydew during the colder winter and early spring months when energy requirements are high, and bodies need to be built up for the onset of breeding. In this case, the scale insect is in the family Coccidae and is probably *Ceroplastes destructor.* As you can see from this photograph, it is not living up to its Latin name of destructor: clearly it is having little impact on this tree that is able to set fruit abundantly and provide nectar to the honeyeater population, even though its own flowers do not. Local birds noted to be using this species of scale insect for its honeydew include Yellow-faced Honeyeater *Lichenostomus Chrysops* and Lewins Honeyeater. Are there are other species in your area doing the same thing?

Assumptions regarding what appears obvious can sometimes lead you astray. Groundsels in the genus *Senecio* are obviously wind-dispersed: each seed topped by a plume. This is clearly effective because they appear in the most surprising spots. But is that the end of the story: how do the seeds get into the soil to be stored in the soil seed bank? The following discovery may provide the answer: very tiny ants have been observed laboriously collecting the fallen seed and dragging it to their burrows (Figures S180, S181). The plant may be duping the animals to collect the seed for no benefit to the ant. It is more likely, though, that the seed is used for food and that the ants are hoarders. In such situations, some of these seed caches can be lost, forgotten or the colony can die out, be disrupted by a digging Echidna or wombat, or a wildfire can pass overhead. In each of these scenarios, the seed has effectively been sown and germinates following the disturbance event. *Senecios* therefore have two dispersal stages, the first is random and widespread, and the second is directional and more local when the ants bury the seed.

It is important not to draw the wrong conclusion in the seed dispersal game. Even though something eats the seed, there is no guarantee that the seed will be successfully transported intact to germinate another day (even for those with a very tough seed-coat like wattles).

THE BRIBE HAS WORKED: THE SEED IS DISPERSED AND IT GERMINATES!

Figure S176. Kanooka Nursery, Orbost. The results of a patient trial ({ }) to see what Swamp Wallabies *Wallabia bicolor* were eating at Nyerimilang showed: three native species were eaten and also dispersed: Seaberry Saltbush *Rhagodia candolleana*, Fireweed Groundsel *Senecio linearifolius* and Forest Nightshade *Solanum prinophyllum*.

Some seed eaters are ***seed predators***, meaning that they actually eat the seed. These animals (mostly birds and some rodents) hull the seed and consume the endosperm itself, thereby killing the seed. They can do this either through the action of a muscular gizzard full of grit (some rainforest pigeons) or by breaking open the seed with their beaks and eating its contents: for example, several parrots: Crimson Rosellas *Platycercus elegans* and King Parrots *Alisterus scapularis* (Figure S182).

King Parrots are especially interesting because they specialise in consuming unripe seeds in green fruits, delicately separating the pulpy endosperm from the unformed outer seed coat (Appendix S10). The consumption of unripe rainforest seed by birds is very unusual in south-eastern Australia and shows a high degree of specialisation (because it subverts the plant's 'intention' of getting its ripe fully coloured fruit and seed dispersed).

ANTS OR BIRDS: WHICH WILL TAKE MY SEED WHERE?

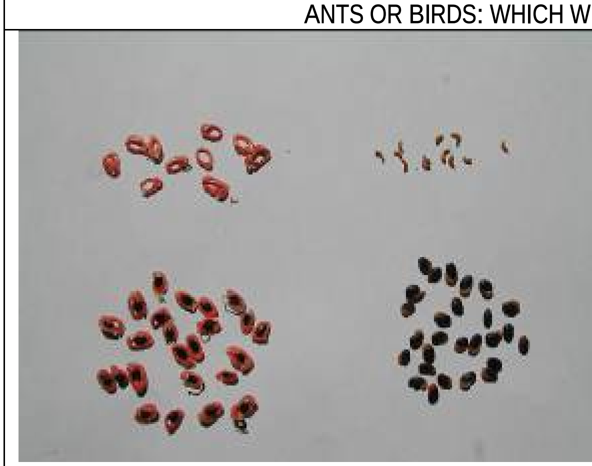

Figure S177. The seed of the non-rainforest Sunshine Wattle *Acacia terminalis* (bottom right) has only a small funicle (top right) that attracts ants to that drag it over small distances (metres). In contrast, the rainforest wattle Blackwood *Acacia melanoxylon* (left) has a large and brightly coloured aril (top left), which attaches it to the pod where it hangs for months to attract birds (Figure S178) which disperse it over many kilometres to other rainforest stands.	Figure S178. Maringa Creek, Nyerimilang Heritage Park, Victoria. Blackwood *Acacia melanoxylon* seed still hanging on the tree 8 months after the pods opened. Note that unlike Sunshine Wattle *Acacia terminalis* (Figure S177) the seed is not explosively expelled from the pod but is suspended by its funicle in clear view for the birds to see, consume and disperse away from the parent tree.

This leads to some interesting interactions for example:

- Wonga Pigeons *Leucosarcia melanoleuca* (reputedly seed predators) will pace around the base of trees in which other birds are feeding waiting patiently for fruits or seed to fall – rarely, if ever, do they go up into the canopy to consume fruit or seed from the plant itself. Rainbow Lorikeets *Trichoglossus haematodus*, on the other hand, are agile climbers and feed in the canopy on rainforest seed. Being parrots, you might expect them to be seed predators. However, they are not (Appendix S10), and will for instance, eat the sweet flesh off the fruits of Wild Cherry *Exocarpos cupressiformis* and drop the seed to the ground where Wonga Pigeons have been observed patiently waiting to eat them. If the pigeon fails to find the seed, then the lorikeet has acted as a successful dispersal agent
- Emerald Doves *Chalcophaps indica* (also reputedly seed predators) will also eat fallen seed or fruit, but take it one step further and actually eat the seed defecated by other rainforest birds (Higgins and Davies 1996). Because the nutriment associated with the voided seed has been consumed by the previous owner (as the fruit), it can be assumed that this species is essentially a granivore, and uses its gizzard to grind up the seed itself.

Other assumptions can also be erroneous. Seeing Crimson Rosellas eating the fruits of Coast Beard-heath *Leucopogon parviflorus* and Common Boobialla *Myoporum insulare* in Littoral Rainforest and hearing them cracking their seeds understandably leads to the conclusion that they are acting as seed predators. Not so! Closer inspection reveals a seed that is very hard and the cracking occurs as the parrots separate the seed from the pulp, and it is the pulp that they actually they eat. The seed itself is dropped intact and consequently dispersed (Figure S183). In rainforest restoration, as in all areas of ecology (and life really), it always pays to test your assumptions before drawing definite conclusions.

INSECT SEED DISPERSAL OF WATTLE SEED WITH FUNICLES: THE EVIDENCE

Figure S179. Bike Track, Snowy River Orbost Victoria. Silver Wattle *Acacia dealbata* seed that has been explosively expelled from pods and then collected by ants (blue circle). The ants have been attracted by the seed's funicle (see Figure S177) then dragged them to the entrance of their burrow. Some of the seed has been abandoned at the entrance once the funicle has been removed.

SEED DISPERSAL: EVEN THE VERY SMALL DO A MIGHTY JOB

Figure S180. Middle Flat Maringa Creek, Nyerimilang Heritage Park, Victoria. Notice anything unusual? The red arrows indicate piles of fluff from the plumes of Fireweed Groundsel *Senecio linearifolius* that were once attached to the seeds, but where were the seeds now?

Figure S181. Middle Flat Maringa Creek, Nyerimilang Heritage Park, Victoria. The answer was revealed upon closer inspection. Small ants have been collecting vast amounts of seed along with their plumes, dragging it to their burrows and then disconnecting the seed from the plume, leaving it around the burrow entrance, before taking the seed itself underground.

MEET A RAINFOREST BIRD THAT SPECIALISES IN UNRIPE FRUIT

Figure S182. Clifton Creek, Victoria. King Parrots *Alisterus scapularis* are unusual amongst birds in that they deliberately seek out unripe fruit (most animals are tuned-in to bright colours so as to disperse ripe fruit and the plant's seed cargo). This means that this parrot searches the foliage for green fruits and, when they are found, it discards the unpalatable flesh and hulls the unripe seed, which is its real prize. With this behaviour, it is a seed predator, not a seed disperser. Photo: Sean Phillipson.

Not all seed dispersers are birds. Mammals can play an important role as well (Figure S184) and, obvious though it is, you must have an animal available to disperse your seed (Figure S185). The exact extent of the role both birds and mammals play in plant dispersal is not yet well understood in our region. Any data you can collect is valuable. The dearth of information was borne out by the scat analysis of Grey-headed Flying Foxes from the Bairnsdale camp, which revealed at least three species not previously recorded in their diet: Rose-leaf Bramble *Rubus rosifolius*, Kangaroo Apple *Solanum aviculare* and Seaberry Saltbush *Rhagodia candolleana*. Observations on the Snowy River added another plant: the Victorian endangered Yellow Elderberry *Sambucus australasica*. These observations also revealed a previously unknown form of feeding behaviour for Grey-headed Flying Foxes. Until these observations (Appendix S10), they had only ever been recorded feeding on plants more than 3m in height. This is because they need at least this height to avoid ending up on the ground after launching from the food plant. However, the consumption of two of these food items (Rose-leaf Bramble, which never gets higher than 1.5m and Yellow Elderberry which was only 1.5m high at the time the fruit was consumed by the flying foxes) suggests another feeding pattern: the snatch and grab method. This theory is further reinforced in that neither plant could support the weight of a flying fox. Until these observations, this inferred feeding behaviour had never before been recorded in Australia!

The role of other mammals as rainforest seed dispersers is even more poorly known. Some very limited scat analysis in East Gippsland has shown that viable rainforest seed is dispersed in the dung of the following animals:

- Brushtail Possums *Trichosurus vulpecula*: Common Boobialla *Myoporum insulare* and Kangaroo Apple *Solanum aviculare*
- Swamp Wallabies *Wallabia bicolor*: Tree Violet *Melicytus dentatus* s.l., Shrubby Fireweed *Senecio minimus*, Forest Nightshade *Solanum prinophyllum* and Seaberry Saltbush *Rhagodia candolleana* (Figure S176)
- Common Wombats *Vombatus ursinus*: Kangaroo Apple *Solanum aviculare*.

Note that the list for Swamp Wallabies also includes species such as *Senecio* that do not have fruits and so do not align with what is traditionally linked to plant dispersal by mammals. Their seed was previously only known to be wind-dispersed, and our discovery of secondary short-distance dispersal by ants. The fact that mammals can also disperse such species sheds a new light on just how many links there may be between browsers and grazers and plant dispersal.!

Although some work has been done on birds by Barker and Vesjens (undated a) and (undated b), almost nothing was known locally of food plants for most of the region's rainforest birds. The data collected by the author and others during rainforest restoration works has substantially added to the national body of knowledge on the subject (Appendix S10). More importantly it has revealed the following important facts:

- Many birds that were previously not thought of locally as rainforest birds disperse rainforest species' seed e.g. Yellow-faced Honeyeaters *Lichenostomus chrysops* and White-naped Honeyeaters *Melithreptus lunatus* (Higgins, Peter and Steele 2001)
- Others recognised as rainforest birds such as Rainbow Lorikeets *Trichoglossus haematodus* did not appear (up until recently) to have a role as seed dispersal agents, but are recorded dispersing Cherry Ballart *Exocarpos cupressiformis* and Tree Broom-heath *Monotoca elliptica,* both of which are important Littoral Rainforest plants
- It is possible to build up a picture of the importance of proximity and contiguity as it relates to individual species that use rainforest and disperse seed within or between rainforest stands. For example, Lewins Honeyeaters *Meliphaga lewinii* are reluctant to travel over open ground, so contiguity of your site with existing bush is important. In contrast, Pied Currawongs *Strepera graculina* are bold and unafraid to travel large distances between patches of bush, so contiguity is (on the surface, not as important)
- Proximity, however, remains an issue because retention of seed is limited to whether it is processed in the crop (and regurgitated within minutes) or ingested and excreted in the dung, in which case retention times are longer. Pied Currawongs *Strepera graculina* are classic regurgitators (Chapter 3: Opener). Currawongs process fruits with large seeds (Blue Oliveberry *Elaeocarpus reticulatus* and Lilly Pilly *Syzygium smithii*) in their crops and then these are regurgitated not far from the feeding site (because this occurs within 5-15 minutes of its consumption (Bass 1989). Others, though, let the seed pass through their gut and the residence time in the gut of the dispersing animal can be variable, depending on the species involved. For example, the small Silver-eye *Zosterops lateralis* retains the seed in their gut for a matter of tens of minutes before it is defecated. Being larger birds, Satin Bowerbirds *Ptilonorhynchus violaceus* are likely to have longer gut-retention times, and consequently longer dispersal distances, for the seeds that they carry.

Seed dispersal: what it tells us and how you can put it all together for your rainforest restoration project?

As can be seen by Figure S170, honeyeaters play an important role in the dispersal of rainforest plants that have fruits (a reproductive structural augmentation that is very common in rainforests). Could this correlation have any role to play in rainforest succession and does this teach us anything about rainforest restoration? If it does, can we put all of this information together on dispersal, fruiting species and the animals that move them across the landscape? Well, here is what we did when trying to work out whether or not rainforest would re-emerge at a very important Littoral Rainforest site at Goalen Head in southern New South Wales. At the time it was bought and added to Mimosa Rocks National Park, it was just a paddock dominated by Kikuyu **Pennisetum clandestinum*. The dilemma was: should significant amounts of public money be applied to replant a rainforest, or could the Littoral Rainforest regenerate there all by itself?

Table S13 investigates these questions and Table S14 compiles the result. The data for this analysis came from Appendix S6 and Appendix S10. Armed with this information, and our knowledge of local *paddock rainforest starters* and rainforest plants, it would seem (we felt), that it was likely that Littoral Rainforest would re-emerge on the site with minimal, but targeted assistance from land managers to deal with any other ecological brakes operating on the site. So, by keeping domestic stock grazing off (one of the brakes), and dealing with any transforming weeds that may be present or may arrive (the other brake), the site should recover its rainforest. (Figures S186, S187 and S188). Table S14 indicates that there is succession involving birds, as well the better understood rainforest succession from the plant perspective.

The lesson here is that, with minimal funds (to deal with any ecological brakes), a substantial and important area of rainforest is re-establishing itself, without the need for massive intervention. Sometimes focused observations and a bit of background research can yield significant insights. With patience, then, money can be saved and past destruction can be healed. Even waiting and observing pays significant dividends: the dominance of Kikuyu in this old paddock is declining in the absence of grazing in favour of the native tussock-forming Kangaroo Grass *Themeda triandra* (Stuart Cameron pers. comm.). Even this native grass in time will also succumb as shade robs it of sunlight. This has two implications: the sward-forming grass is no barrier to the pioneer and early secondary species establishment, and tussock species aid in the establishment of primary rainforest species.

ALWAYS TEST ASSUMPTIONS BEFORE JUMPING TO CONCLUSIONS

Figure S183. East Gippsland Garden, Nyerimilang Heritage Park, Victoria. Fruit from Common Boobialla *Myoporum insulare* taken from beneath a tree in which Crimson Rosellas appeared to be destroying the seed. A closer inspection revealed the seed that they were assumed to be cracking open while consuming the fruit was in fact intact, so our earlier conclusions that this parrot was a seed predator of Boobialla were incorrect.

SEED DISPERSAL CAN OVERCOME MANY HURDLES, BUT THE DISPERSING AGENT MUST BE PRESENT

Figure S184. Maringa Creek, Nyerimilang Heritage Park, Victoria. Swamp Wallabies *Wallabia bicolor* are drawn to the sweet smell of this ripe Forest Nightshade *Solanum prinophyllum*. They will brave these ferocious spines to get to its succulent delights. Simple nursery trials of sowing wallaby scats showed that this species successfully spread viable seed of this species (Figure S176).

Figure S185. Bairnsdale, Victoria. A commercial courtyard rainforest planting of White Elderberry *Sambucus gaudichaudiana* in fruit. It shows a sad sight: the planting has not attracted a fruit eating animal to disperse its seeds.

Hoarders
Some species are recorded as seed hoarders. These species hoard seed supplies in caches for later use. If the cache is forgotten, lost or not visited before germination, successful seed dispersal has occurred. Local species that may fulfil this role include:

- Buff-banded Rails *Gallirallus philipensis* are recorded as food hoarders (Marchant and Higgins 1993) and this perhaps implicates them in rainforest seed dispersal. In addition, they are locally considered to be important in rainforest ecology because they behave like lyrebirds: scratching over the rainforest mulch along rivers and accelerating the conversion of organic nutrients bound up in fallen plant material and converting it to mineral nutrients for reuse by the plants
- Swamp Rats *Rattus lutreolus* are another hoarder of food (Museum of Victoria Bioinformatics Online). Its diet is mainly grasses and sedges, but this is supplemented by fruits and seeds. If it caches any of these, then it too may be important in dispersal and establishment of rainforest plants, with species such as Large Bindweed *Calystegia sepium* collected in huge quantities in autumn (Appendix S10).

Wind and water
These two agents are also important in getting rainforest seed onto your restoration site. Dissemination of seed by water is directional and, for rainforest, is mostly associated with rivers, but is not necessarily restricted to flood events. Littoral Rainforests also have seed dispersed by water in estuaries (Saw-sedges *Carex* spp., Rushes *Juncus* spp., Common Boobialla *Myoporum insulare*, Muttonwood *Myrsine howittiana* and Common Reed *Phragmites australis*) and the open sea (Scurvy-weed *Commelina diffusa* and New Zealand Spinach *Tetragonia tetragonioides*). As a consequence, the connection of your Littoral Rainforest restoration site to water or a beach can help with plant dispersal. Interestingly, fragments of Scurvy-weed are also dispersed by water. Figure S189, shows the results of some local experiments investigating the possible role of water dispersal for Littoral Rainforest plants.

The most startling result illustrated in Figure S189 (that of Muttonwood *Myrsine howittiana*) has some very strong correlations to the observed pattern of its distribution in both Warm Temperate Rainforest along rivers and in Littoral Rainforests around estuaries where, as an adult tree, it tolerates considerable periods of inundation, by both fresh and saline water. It is the last rainforest canopy dominant species to persist before the frequency of inundation favours the swamp-based EVC zones.

In contrast to water-based seed dispersal, wind is much more random in its seed delivery across the landscape. This is compensated for by the production of large amounts of seed (e.g. Clematis) or seed that can be stored in the soil seed bank for many decades or even centuries, such as members of the daisy family including: Fireweeds: *Senecio* spp.; Everlasting daisies: *Helichrysum* spp.; *Bracteantha* sp. and *Ozothamnus* spp.; Dogwoods *Cassinia* spp.; and Cudweeds *Euchiton* spp.). Studies on Littoral Rainforest strongly suggest that wind-dispersed species arrive more rapidly in greater numbers and diversity than do animal-dispersed fruiting species in the early stages of a rainforest stand's development. This includes vines such as Love-creeper *Comesperma volubile*, Forest Clematis *Clematis glycinoides* and Wonga Vine *Pandorea pandorana,* and the Fireweeds *Senecio* spp. In a study at Mallacoota, dispersal distances documented are comparatively short for heavier seeded vines such as Forest Clematis and Wonga Vine. Dispersal events for species with seed as fine as dust (e.g. orchids) may involve incredible distances, even allowing them to travel between continents.

There are some important actions that you, as the rainforest restorer, can take to enhance the amount of wind and water-based seed dispersal reaching your restoration site. For wind-dispersed species this includes:

- Plant early pioneer species that will recharge your soil seed bank with native plants (members of the daisy, pea, solanum and wattle families are particularly important) because they disperse throughout your restoration site and to adjacent sites
- Ensure that the daisy species are conserved as much as possible during weeding programs because subsequent seasons will see an explosion in their numbers in your works area (removing the need to hand plant such species, either in the next year or in the future). Because they are unpalatable, they play a really important role in rainforest succession: hiding more palatable species (e.g. wattles) that come along later in the successional sequence (Appendix S11: Figure AS11-5)
- On highly degraded sites (provided there are not a great abundance of transforming soil-stored weeds present), try to weed at least some of your site back to bare ground, because this is the preferred germination niche for most of these species. We have noted that Common Wombats *Vombatus ursinus* will do this for you, thus acting as ***ecosystem engineers*** (Lindenmayer 2008) and germination of wind-dispersed species follows.

Table S13. Proposed natural rainforest restoration pathway for *Goalen Head* Littoral Rainforest based on local bird species and their diet.

Fruit dispersing species	Red Wattlebird	Brush Wattlebird	Yellow-faced Honeyeater	Australian Raven	Silver-eye	Lewins Honeyeater
PIONEER SPECIES	*Einadia nutans*					
	Acacia longifolia ssp. sophorae			*Acacia longifolia ssp. sophorae*		
	Solanum aviculare	*Solanum aviculare*		*Solanum aviculare*	*Solanum aviculare*	*Solanum aviculare*
						Solanum vescum
						Omolanthus stirlingifolius
SECONDARY SPECIES						*Trema aspera*
				Brachychiton populneus		*Brachychiton populneus*
	Rhagodia candolleana	*Rhagodia candolleana*	*Rhagodia candolleana*	*Rhagodia candolleana*	*Rhagodia candolleana*	*Rhagodia candolleana*
	Myoporum insulare	*Myoporum insulare*		*Myoporum insulare*	*Myoporum insulare*	*Myoporum insulare*
	Leucopogon parviflorus	*Leucopogon parviflorus*	*Leucopogon parviflorus*	*Leucopogon parviflorus*	*Leucopogon parviflorus*	*Leucopogon parviflorus*
	Exocarpos cupressiformis		*Exocarpos cupressiformis*	*Exocarpos cupressiformis*	*Exocarpos cupressiformis*	*Exocarpos cupressiformis*
			Rubus moluccanus		*Rubus moluccanus*	*Rubus moluccanus*
			Rubus parviflorus		*Rubus parviflorus*	*Rubus parviflorus*
			Rubus rosifolius		*Rubus rosifolius*	*Rubus rosifolius*
			Polyscias sambucifolia ssp. 1		*Polyscias sambucifolia ssp. 1*	*Polyscias sambucifolia ssp. 1*
					Omolanthus nutans	*Omolanthus nutans*
	Amyema pendula	*Amyema pendula*	*Amyema pendula*			
		Acacia mearnsii				
		Amyema congener				
		Amyema miquelli				
			Acacia melanoxylon			*Acacia melanoxylon*
		Muellerina eucalyptoides				
			Muellerina celastroides			
						Breynia oblongifolia
						Claoxylon australe
						Dendrochnide excelsa
		Monotoca elliptica				*Monotoca elliptica*
						Acacia maidenii
						Stephania japonica
						Elaeocarpus reticulatus
						Enchylaena tomentosa
PRIMARY SPECIES				*Ficus coronata*		*Ficus coronata*
				Ficus obliqua	*Ficus obliqua*	*Ficus obliqua*
				Ficus rubiginosa		*Ficus rubiginosa*
			Hedycarya angustifolia			*Hedycarya angustifolia*
			Coprosma quadrifida	*Coprosma quadrifida*	*Coprosma quadrifida*	*Coprosma quadrifida*
			Melicytus dentatus	*Melicytus dentatus*	*Melicytus dentatus*	
					Pittosporum undulatum	*Pittosporum undulatum*
					Myrsine howittiana	*Myrsine howittiana*
					Celastrus australis	*Celastrus australis*
						Sambucus austalasica
						Ehretia acuminata
						Syzygium smithii
						Ficus obliqua
						Eustrephus latifolius
						Morinda jasminoides
						Eupomatia laurina
		Sambucus australasica				*Sambucus australasica*
						Dianella caerulea

Table S14. Summary of natural rainforest restoration pathway for *Goalen Head* Littoral Rainforest based on local bird species and their diet.

Fruit dispersing species	Red Wattlebird	Brush Wattlebird	Yellow-faced Honeyeater	Australian Raven	Silver-eye	Lewins Honeyeater
Coast Banksia Woodland (*Pi**)						
Young Rainforest (*ES/LS**)						
Mature Rainforest (*Pr**)*						
TOTAL Primary species (Pi)	3 (38%)	1 (9%)	0	2 (20%)	1 (6%)	3 (1%)
TOTAL Secondary species(ES/LS)	5 (62%)	9 (82%)	10 (77%)	5 (40%)	9 (56%)	20 (50%)
TOTAL Primary species (Pr)	0	1 (9%)	3 (23%)	5 (40%)	6 (38%)	17 (42%)
TOTAL Rainforest species	8	11	13	12	16	40

*Successional stage terminology is explained in the **Glossary** and Definitions and Synonymy and their successional stage classification is provided in **Appendix** S6.

THE AREAS TO RECOVER ARE VAST

Figure S186. Goalen Head, New South Wales. Remnant rainforest stands are no more than a cluster of shrubs, and the former rainforest (potentially ~70ha) is vast.

AND SO IT BEGINS

Figure S187. Goalen Head, New South Wales. Paddock Rainforest starters (Coast Banksia *B. integrifolia*) have begun converting the pasture to forest.

NATURE IS GRAND: RAINFOREST IS ON THE WAY

Figure S188. Goalen Head, New South Wales. Rainforest successional processes are underway and rainforest is re-occupying its former home.

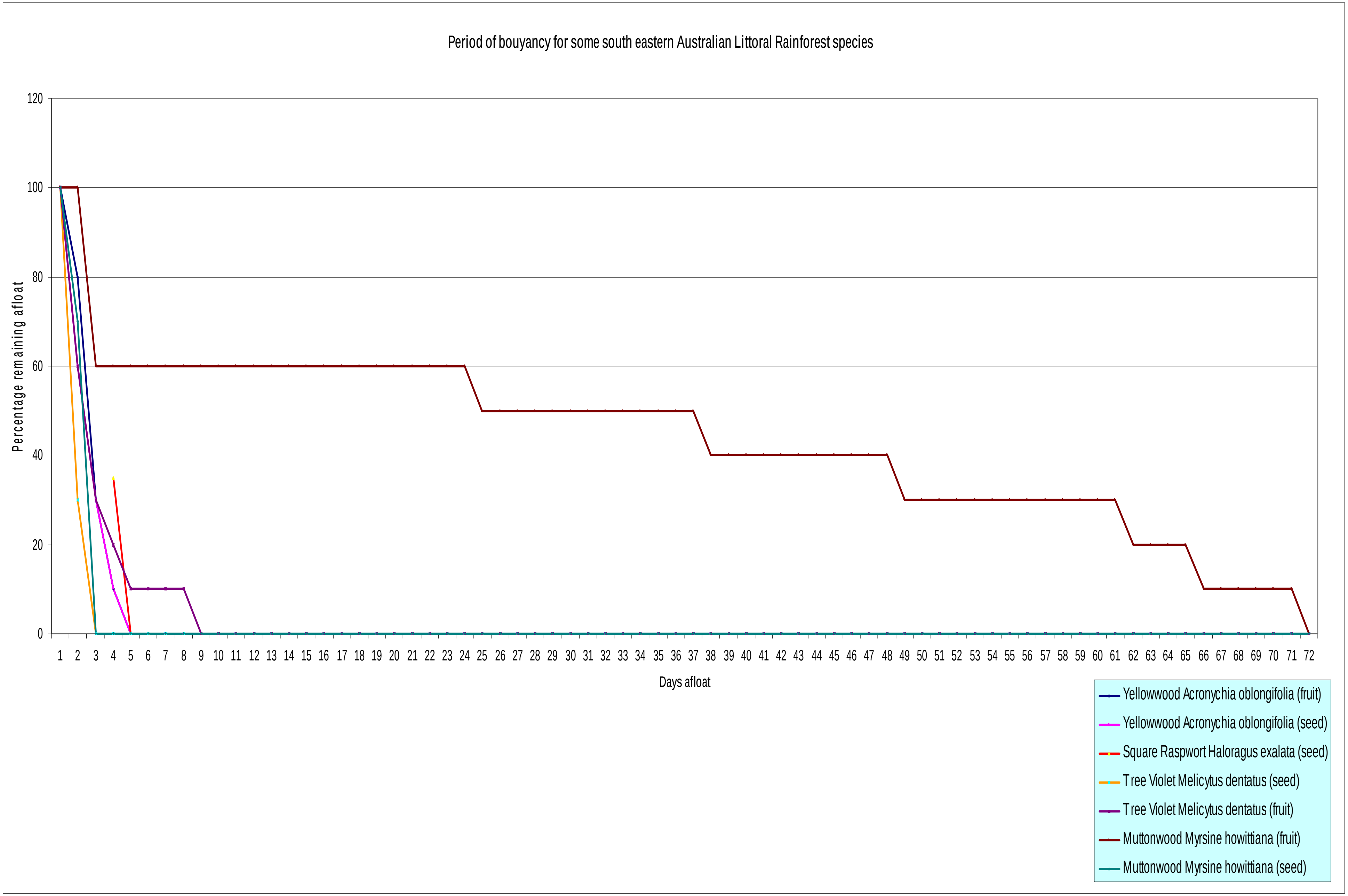

Figure S189. Flotation periods for some Littoral Rainforest species from south-eastern Australia.

For water-based seed dispersers:

- Control large woody weeds on the toe of the bank (especially along the waterline for water-borne seed dispersers). Willows **Salix* spp. and Grey Poplars **Populus* X *canescens* are a prime example here, and their control removes an important ecological brake (lack of light) that prevents waterline and bank regeneration. This simple action releases this niche for the rapid establishment of a huge range of semi-aquatic species and rainforest species (Figure S189). This habitat is very important in stabilising the toe of the bank in rainforest restoration sites along rivers. Species that colonise this niche include: Common Reed *Phragmites australis*, Rushes *Juncus* spp., Club-sedges (*Schoenoplectus* spp. and *Bulboschoenus* spp.) and Bulrushes *Typha* spp. (Chapter S5: Figure S190). These species also provide important fish habitat and food and breeding sites for wetland birds, such as the Buff-banded Rail
- These beds of semi-aquatic plants then trap small areas of damp silt that in turn provide habit for the germination of the seed of Kunzeas *Kunzea* spp., Tea-trees *Leptospermum* spp. and Honey Myrtles *Melaleuca* spp. (all of which are important in attracting abundant and diverse insect pollinators that become fish food), and Bottlebrushes *Callistemon* spp. (important for nectar-dependent species). This process of bank accretion ultimately builds new stream banks that can, in time, become rainforest habitat. It took just 15 years for this to happen at Hendersons downstream of Lochend Jungle on the Snowy River.

SUMMARY	
COMPREHENSION: STOP	An understanding of ecological theory, ecological principles and ecological processes is fundamental to being able to design, implement and understand the results of rainforest restoration.
KNOWLEDGE: THINK	It is imperative that you understand or learn these concepts before, during and in the review stage of your rainforest restoration project.
WHAT TO DO? ACTION	Understand every action that you undertake on your rainforest restoration site and in the local landscape (urban areas, bushland, etc.) in the context of rainforest ecology. The insights that such an approach provides will help smooth the way for your restoration works and project success. The knowledge gained once you comprehend the ecology of rainforests in general, and of your rainforest site in particular, will enable you to come to grips with any problems that may arise and this will enable you to conceptualise possible solutions and implement them.
WHAT NEXT?	Now that you have an appreciation of the ecology that underpins rainforests, it is time to lift your gaze to **the landscape**. **Landscape dynamics influence your rainforest site** by affecting: • What you can do • When you can do it • How you can do it • How fast you can do it • How much you can do and what you may wish to leave to nature to achieve on your behalf.