JUNE 2019
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Trees For Bees

RIPARIAN PLANTING HANDBOOK

How to Incorporate Bee Forage into Riparian Planting

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Callaghan Farm, mid Canterbury.
Native riparian planting at 18 months.

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Front Cover Photo: Fenced Trees for Bees riparian planting after 2 years at Puketiti Station, King Country.
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PREFACE

The Trees for Bees NZ research programme aims to encourage all landowners to consider selecting bee forage plants whenever they are planting for other purposes such as shade and shelter, land stabilisation, biodiversity or riparian protection.

The information presented in this handbook is targeted to riparian protection planting specifically and aimed at assisting honey bee colonies in particular. Honey bees are the most important and premier pollinator for all temperate zone agricultural economies in the world including New Zealand. Although, all pollinators are important and need to be protected, honey bees in particular are the most significant and critical pollinators because they are domesticated to live in moveable hives that can be rapidly transported to any site in need of pollination services (Newstrom-Lloyd 2013).

For this reason, the Trees for Bees NZ research programme has focused primarily on honey bee plants but most other pollinators, both insects and birds, will also benefit from the same flowering plants that we use for honey bee pollen and nectar sources. Whether we are planting for all pollinators including birds; or for all pollinating insects (bees, moths, butterflies, beetles etc.) or just for bee only including native, honey and bumble bees; we find the same flowering species to be useful most of the time. Many flower types are shared by birds and a wide range of insect pollinators, for example native New Zealand flax (Figures 1 and 2). Many native and

Figure 1. Native bee (Hylaeus) *collecting pollen from NZ Flax flower*

Figure 2. Honey bee collecting pollen from NZ Flax flower.

Figure 3. Native bee on exotic Melaleuca flowers

Figure 4. Bumble bee on native manuka flower

exotic flowering plants are shared by native bees and honey bees as well as bumble bees. Native bees visit exotic plants (Figures 3) and honey bees and bumble bees visit native plants (Figure 4). Some differences in preferences do exist however, for example, bumble bees will favour more complex closed flowers that are difficult for native bees or honey bees to access for nectar or pollen (Figure 5).

The most important difference in planting for native bees, honey bees or bumble bees is the timing of the seasons when the most flower resources are needed by each type of bee. Most plants in New Zealand flower in the summertime which matches the season of the most activity for native bees. Honey bees on the other hand need to have more abundant flowers in spring and autumn before and after pollination services and honey harvesting while bumble bees need to have flowers in the very early spring when the solitary queens are first emerging.

In this handbook we show how to use flowering calendars to plan bee plantations that match when the most pollen and nectar are needed by honey bees. By shifting and adjusting the flowering calendar, the same principles can be used to benefit native or bumble bees or other pollinators including moths, butterflies and birds. This means that much of the information and guidelines in this handbook can be used for planning plantations for any mix of pollinators including general biodiversity plantations by simply adjusting the flowering calendar and slightly modifying the plant lists.

Our Trees for Bees NZ results are based on ten years of research working with landowners, beekeepers, and nurseries installing bee forage plants, collecting data on pollen nutrition, and making observations on all types of bees visiting flowers. The Trees for Bees NZ research programme, has been supported by the Ministry of Primary Industries Sustainable Farming Fund and sponsors from the apicultural and agricultural industries as well as regional councils and nurseries since 2009.

In our research we have determined the best multi-functional bee forage plants to cover two critical flowering times – spring and autumn – when honey bees are most at risk for pollen and nectar shortages. We have incorporated selected high-performance bee forage plants into effective

Figure 5. Bumble bee on exotic Lathyrus flower, a complex closed flower.

on-farm and apiary site planting designs to reduce the deficits in honey bee forage. Since 2011, Trees for Bees NZ has set up twenty-seven demonstration farms with over 65,000 bee forage plants established in the North and South Islands of New Zealand. These demonstration farms range from sheep and beef farms, arable farms, vineyards and horticultural areas to home bee yards where queen-raising and overwintering operations are conducted by commercial beekeepers. Riparian bee forage plantings have been a part of many of these demonstration farms.

Happy planting.

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June 2019

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1 INTRODUCTION

The protection of riparian zones is of critical importance to the survival and quality of our waterways. To help achieve these goals there are a number of local, regional and national initiatives to improve water quality through reducing sediment and nutrient runoff. This includes supporting the fencing and planting of riparian zones, especially on farms (see https://www.mpi.govt.nz/growing-and-harvesting/land-care-and-farm-management/farm-management-for-healthy-waterways/). Riparian planting is ideally suited to the establishment of bee forage plants – based on either native or exotic or a mix of both flowering species.

This handbook is intended to provide practical advice to beekeepers, farmers, landowners and sustainability programme managers considering establishing riparian planting. This handbook is complementary to existing riparian planting guides because our focus is on how to incorporate honey bee forage plants into the species mix that is already being planned for riparian plantations. The purpose of this handbook is not to replicate the advice of other agencies on riparian planting, but to show how honey bee forage species can be included in riparian planting in order to achieve multiple benefits for riparian protection as well as honey bees and other pollinators. We present lists of bee forage plants, outline how to plant for honey bees, how to work with the flowering calendar to balance the annual honey bee forage budget and illustrate case studies of riparian plantations designed to benefit honey bees.

There are a number of reasons for including honey bee forage plants in your riparian plantation. You may simply want to play a role in helping honey bees by integrating a mix of bee plants in the riparian planting for year-round flowering. Or you may wish to focus your planting specifically for spring and autumn flowering, as these are the critical times of year when honey bee forage is lacking. Or you may need to improve pollination or honey harvesting activities on your farm or in your area by increasing honey bee health and numbers. Finally, you may wish to benefit specific apiary sites on your own land or in your area by supporting designated apiary sites for home yards, queen-raising, or overwintering sites with spring or autumn flowering. This handbook will provide you with information and resources to help meet your goals for any of the above reasons to include bee forage in riparian zones.

The problem of insufficient bee forage for honey bees has two main causes: the increase in number of hives and apiaries and, the continuing loss of bee forage plants on and off farms. Recently, the apiculture industry has been expanding at an unprecedented rate. The number of honey bee hives in New Zealand has increased exponentially in the last 8 years from around 350,000 hives to around 900,000 hives. Meanwhile, the floral resources that are needed to feed pollen and nectar to honey bees have not increased significantly. In fact, floral resources have been steadily diminishing due to ongoing loss of bee habitat, the rise of weed-free agricultural practices and other land use changes such as removal of gorse and willow – two of the premier bee forage species that beekeepers have relied on in the past. Gorse and willow are invasive plants that must be removed in many regions so replacement of the lost floral resources is a significant issue.

To alleviate the problems of loss of bee habitat, overcrowding and overstocking associated with the rapid expansion of hive numbers, the apiculture industry has recognised that more installations of bee forage plants are required. The two critical times for honey bees are in spring and autumn when pollen and nectar dearth are often very high. In spring, honey bee colonies are building up their populations from low levels over winter to peak levels that can provide pollination services and honey harvests in summer. In autumn, bee colonies must raise strong young bees to survive the overwintering period. Adding new bee forage plants that flower in spring and autumn helps to make up for lost floral resources to meet the demand from the increasing hive numbers. This will promote a long-term sustainable and profitable apiculture industry which, in turn, supports pollination services in agriculture for the arable, horticultural, and pastoral sectors. Since, our food security relies on pollination services, the support of bees is of importance to everyone.

2 RIPARIAN BEE PLANT SPECIES

Many of the species listed in the riparian guidelines are excellent honey bee forage plants including native species, willows and other exotic species. The wealth of options for creating a riparian planting that also functions as good bee forage is shown in the plant lists below. It is generally a simple exercise to make bee plant selections for spring and autumn flowering in order to balance out the **annual bee forage budget** for pollen and nectar (see glossary for definition of terms in bold and the explanation in section 4.3 and 4.4). The first step is to make a **flowering calendar** and from that a **species diversity chart.** This will show how many candidate species you could use that are flowering in each month of the year and will enable you to ensure that the spring and autumn seasons are well covered.

We work with the flowering times to create a bee plantation. The flowering times for bee plant species are shown in the plant lists that can be downloaded from www.treesforbeesnz.org/information and in other sources such as nursery catalogues and conservation or regional websites. Once a flowering calendar and a species diversity chart are created then the same type of information can be used to portray the number plants needed for each species by creating a bee forage profile that will serve to make the annual bee forage budget. The budget can be adjusted to match the particular requirements for any given plantation scenario or goal. This is done by adjusting the number of plants for each bee plant species in the chart so that the desired annual bee forage budget is achieved (see examples below in Figures 23 to 25).

To show which plants are most useful and practical for honey bee forage in riparian zones, we have surveyed all the currently available regional council riparian planting lists and other publications to cross reference with our bee plant lists as shown in the tables below.

2.1 Native riparian bee plants

The majority of plants promoted for riparian planting are native species (see https://www.treesthatcount.co.nz/resources/regional-guides-for-planting-natives/). Native species are encouraged in many regions and often attract funding that is not available for riparian planting of exotic species. Native species are also encouraged in areas adjacent to existing native vegetation, to minimise the risk of creating a weed issue from exotic plants invading the native vegetation. Many native plant species provide excellent honey bee forage as both pollen and nectar sources. These same species are shared with and also support native pollinators and bumble bees. A well-designed planting programme supporting bees and other pollinators will not only achieve riparian protection goals for the waterway but also will help biodiversity and habitat restoration.

National list of native riparian bee plants

The following national plant list (Figure 6 and Table 1) is derived from a survey of riparian planting guides as produced by the Department of Conservation (DOC) and regional councils from Northland to Southland. The list excludes sedges, grasses and ferns which are not the best pollen and nectar sources but do play an important role in riparian planting. It also excludes some of the larger tree species such as the podocarps and beeches because these do not reliably flower in abundance every year and often skip multiple years. While these excluded plants may produce pollen suitable for bees (especially the beeches), the emphasis we used for good bee forage is on plants that flower reliably every year.

This list of 74 species is the result of cross-referencing the riparian lists with the Trees for Bees plant database to check that they are known to be useful as bee forage plants. The list covers all of New Zealand, and it is recommended you use this as a starting point and then consult locally as to which species are best suited to your area. Note that it also possible to include other locally favoured species not on the following lists. The main requirement is that the plant has flowers that produce adequate pollen and/or nectar.

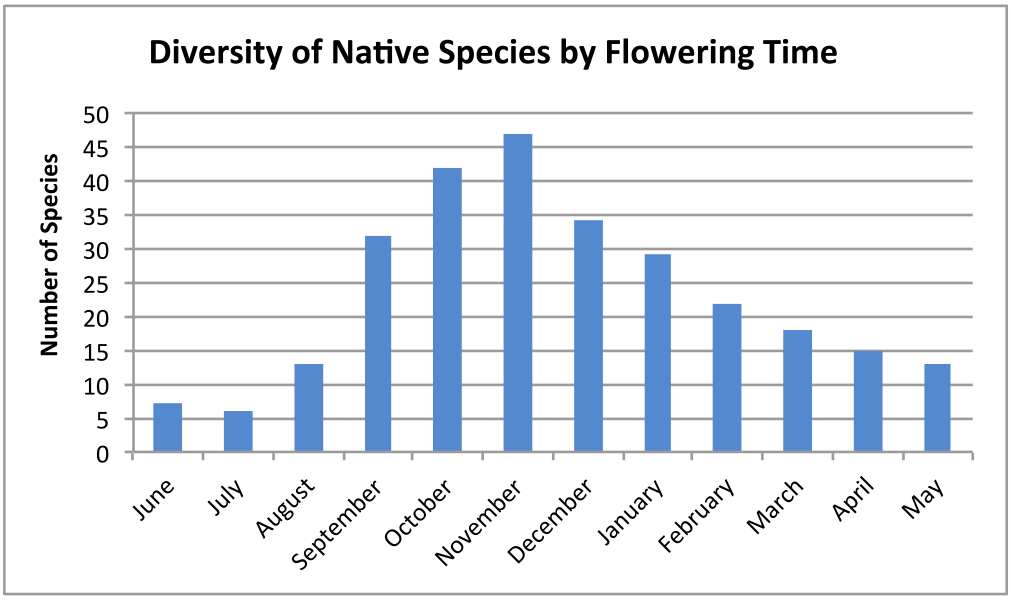
From the species diversity chart (Figure 6), it is apparent that most native riparian bee plant species flower in spring and summer, with smaller numbers in winter. Many of the native species are generalist flowers that accommodate many different types of pollinators such as cabbage tree (Figure 7).

Figure 7. Cabbage tree (Cordyline australis) in flower (age 4 years)

Botanical Name	Common Name	Botanical Name	Common Name
Alectryon excelsus	Titoki	*Lophomyrtus obcordata*	Rohutu
Aristotelia serrata	wine berry	*Macropiper excelsium*	kawakawa
Beilschmedia tawa	Tawa	*Melicytus micanthrus*	Manakura, swamp mahoe
Carpodetus serratus	putaputaweta	*Melicytus ramiflorus*	mahoe
Clematis paniculata	Puatataua	*Myrsine australis*	mapou, red matipo
Coprosma grandifolia	Kanono	*Myrsine divaricata*	Weeping matipo
Coprosma lucida	shining karamu; kakaramu	*Neomyrtus pedunculata*	Rohutu
Coprosma propinqua	mikimiki, mingimingi	*Olearia albida*	tanguru
Coprosma repens	Taupata	*Olearia cheesmanii*	Streamside tree daisy
Coprosma rigida	Streamside coprosma	*Olearia furfuracea*	Akepiro
Coprosma robusta	karamu	*Olearia lineata*	Small-leaved tree daisy
Coprosma tenuicaulis	swamp coprosma	*Olearia paniculata*	Akiraho, Golden AkeAke
Cordyline australis	cabbage tree, ti kouka	*Olearia rani*	Heketara
Corokia buddleioides	korokia-taaranga	*Olearia solandri*	Coastal tree daisy
Corokia cotoneaster	corokia	*Parsonsia heterophylla*	NZ Jasmine
Dodonea viscosa	akeake	*Pennantia corymbosa*	Kaikōmako
Dracophyllum filifolium	Inaka	*Phormium cookianum*	Mountain flax
Dysoxylum spectabile	kohekohe	*Phormium tenax*	flax, harakeke
Elaeocarpus dentatus	Hinau	*Pittosporum crassifolium*	Karo
Elaeocarpus hookerianus	Puka	*Pittosporum eugenioides*	lemonwood, tarata
Fuchsia excorticata	tree fuchsia; kotukutuku	*Pittosporum ralphii*	Karo
Geniostoma rupestre var. ligustrifolium	Hangehange	*Pittosporum tenuifolium*	kohuhu
Griselinia littoralis	broadleaf	*Plagianthus divaricatus*	Saltmarsh ribbonwood
Hebe odora	koromiko	*Plagianthus regius*	ribbonwood
Hebe parviflora	koromiko	*Pomaderris kumeraho*	kumarahou; golden tainui
Hebe salicifolia	Koromuka	*Pseudopanax arboreus*	five-finger; whauwhaupaku
Hebe stricta	koromiko	*Pseudopanax colensoi*	mountain five-finger; orihou
Hedycarya arborea	pigeonwood	*Pseudopanax crassifolius*	lancewood, horoeka
Hoheria angustifolia	Narrow leaved Houhere	*Pseudopanax laetus*	large leaved five finger
Hoheria populnea	lacebark	*Pseudowintera colorata*	horopito
Hoheria sexstylosa	lacebark	*Rhopalostylis sapida*	Nikau palm
Knightia excelsa	rewarewa	*Schefflera digitata*	seven-finger; pate; patete
Kunzea ericoides	kanuka	*Sophora microphylla*	kowhai; weeping kowhai
Laurelia novae-zelandiae	pukatea	*Sophora tetraptera*	large-leaved kowhai
Leptecophylla juniperina	Prickly mingimingi	*Syzygium maire*	swamp maire
Leptospermum scoparium	manuka	*Vitex lucens*	puriri
Leucopogon fasciculatus	Soft mingimingi	*Weinmannia racemosa*	kamahi

Table 1. List of native bee forage species included in riparian plant guides throughout New Zealand.

Figure 6. National level species diversity chart for native riparian bee forage species by month of flowering.



Omarama Station: fenced drain planted with a mix of native and exotic species.

Most widely used native riparian bee plants

We selected the 23 most widely used riparian plant species in the guides. These plants are listed below in rank order from the plant species listed in the most regions of New Zealand to those that are listed in the least regions (Table 2). The most widely used is cabbage tree (Cordyline australis), common throughout New Zealand (Figure 7). Again, the species diversity chart (Figure 8) shows that most riparian species on the lists flower in spring and summer.

Most widely used native riparian bee plants in the North Island

We recalculated the rank for the most widely used riparian bee plant species separately for the North and South Islands to compare the resulting species diversity charts for flowering time. For the North Island, there are proportionately more species flowering in the autumn and over winter (Figure 9 and Table 3) than the most widely used species nationally (Figure 8). This should make it more straightforward to develop a balanced honey bee forage profile in the North Island for spring and autumn based solely on native species whilst maintaining sufficient plant diversity.

Most widely used native riparian bee plants in the South Island

In the South Island the species diversity chart for bee forage species shows that there are proportionately fewer autumn and winter flowering native species (Figure 10 and Table 4) than the most widely used species nationally (Figure 8) which makes it more challenging to develop a balanced bee forage profile in the South Island for spring and autumn based solely on native species whilst maintaining sufficient diversity. This is expected since it is much colder for a longer season in the South Island so the diversity in the autumn through winter for bee forage will be lower.

Botanical Name	Common Name
Cordyline australis	cabbage tree, ti kouka
Leptospermum scoparium	manuka
Phormium tenax	flax, harakeke
Coprosma robusta	karamu
Coprosma propinqua	mikimiki, mingimingi
Kunzea ericoides	kanuka
Sophora microphylla	kowhai; weeping kowhai
Aristotelia serrata	wine berry
Melicytus ramiflorus	mahoe
Plagianthus regius	ribbonwood
Pittosporum tenuifolium	kohuhu
Pseudopanax arboreus	five-finger; whauwhaupaku
Hebe stricta	koromiko
Griselinia littoralis	broadleaf
Myrsine australis	mapou, red matipo
Pittosporum eugenioides	lemonwood, tarata
Carpodetus serratus	putaputaweta
Fuchsia excorticata	tree fuchsia; kotukutuku
Laurelia novae-zelandiae	pukatea
Pseudopanax crassifolius	lancewood, horoeka
Dodonaea viscosa	akeake
Hedycarya arborea	pigeonwood
Schefflera digitata	seven-finger; pate; patete

Table 2. List of native bee forage species in order of the most widely used in riparian plant guides throughout New Zealand.

Botanical Name	Common Name
Cordyline australis	cabbage tree, ti kouka
Leptospermum scoparium	manuka
Phormium tenax	flax, harakeke
Coprosma robusta	karamu
Kunzea ericoides	kanuka
Coprosma propinqua	mikimiki, mingimingi
Hebe stricta	koromiko
Sophora microphylla	kowhai; weeping kowhai
Aristotelia serrata	wine berry
Melicytus ramiflorus	mahoe
Pseudopanax arboreus	five-finger; whauwhaupaku
Pittosporum eugenioides	lemonwood, tarata
Pittosporum tenuifolium	kohuhu
Plagianthus regius	ribbonwood
Carpodetus serratus	putaputaweta
Laurelia novae-zelandiae	pukatea
Myrsine australis	mapou, red matipo
Schefflera digitata	seven-finger; pate; patete
Alectryon excelsus	titoki
Dodonaea viscosa	akeake
Fuchsia excorticata	tree fuchsia; kotukutuku
Griselinia littoralis	broadleaf
Hoheria populnea	lacebark
Hoheria sexstylosa	lacebark
Phormium cookianum	Mountain flax
Pseudopanax crassifolius	lancewood, horoeka
Syzygium maire	swamp maire

Table 3. List of bee forage species in order of the most widely included in riparian plant guides for the North Island.

Botanical Name	Common Name
Coprosma propinqua	mikimiki, mingimingi
Coprosma robusta	karamu
Cordyline australis	cabbage tree, ti kouka
Griselinia littoralis	broadleaf
Leptospermum scoparium	manuka
Phormium tenax	flax, harakeke
Plagianthus regius	ribbonwood
Sophora microphylla	kowhai; weeping kowhai
Aristotelia serrata	wine berry
Coprosma lucida	shining karamu; kakaramu
Elaeocarpus hookerianus	Puka
Fuchsia excorticata	tree fuchsia; kotukutuku
Hebe salicifolia	Koromuka
Kunzea ericoides	kanuka
Melicytus ramiflorus	mahoe
Pennantia corymbosa	Kaikōmako
Pittosporum tenuifolium	kohuhu
Pseudopanax arboreus	five-finger; whauwhaupaku
Pseudopanax crassifolius	lancewood, horoeka
Carpodetus serratus	putaputaweta
Dodonaea viscosa	akeake
Hedycarya arborea	pigeonwood
Hoheria angustifolia	Narrow leaved Houhere
Lophomyrtus obcordata	Rohutu
Myrsine australis	mapou, red matipo
Myrsine divaricata	Weeping matipo
Pseudowintera colorata	horopito

Table 4. List of bee forage species in order of the most widely included in riparian plant guides for the South Island.

Figure 8. Species diversity chart for most widely used native riparian bee species by month of flowering.

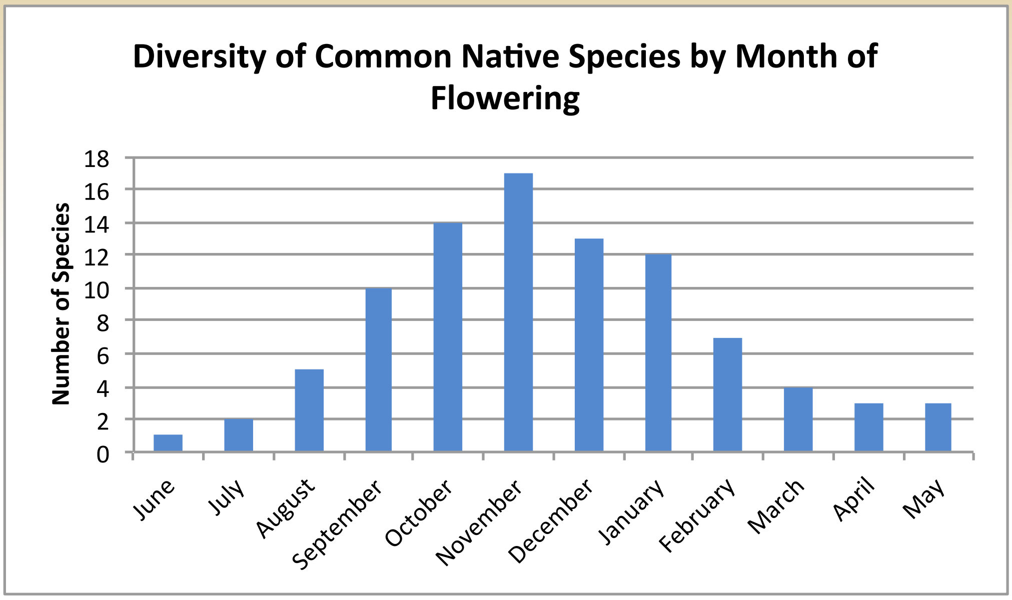


Figure 9. Species diversity chart for the most widely used North Island native bee species by month of flowering.

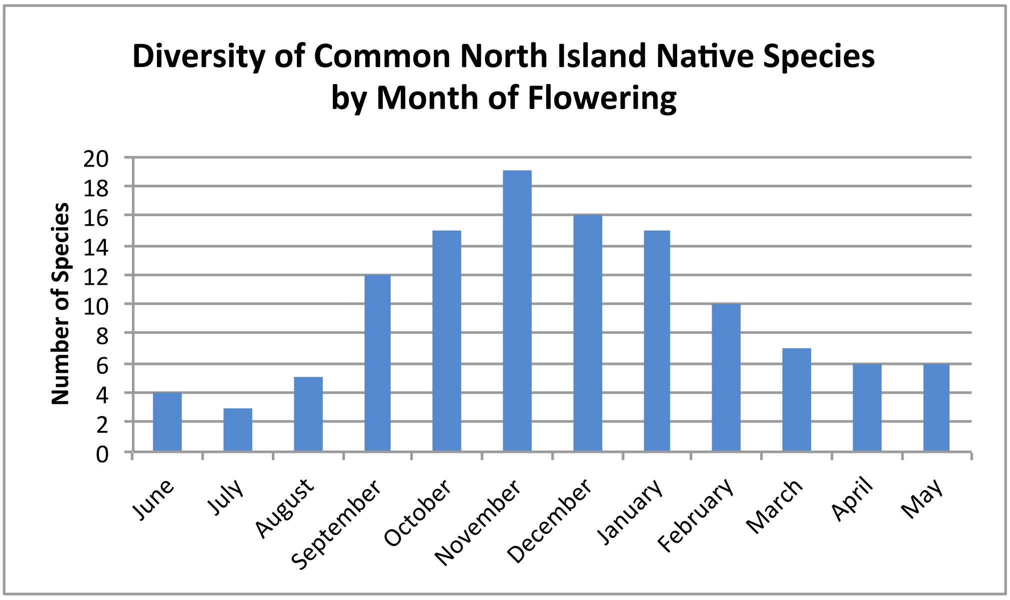
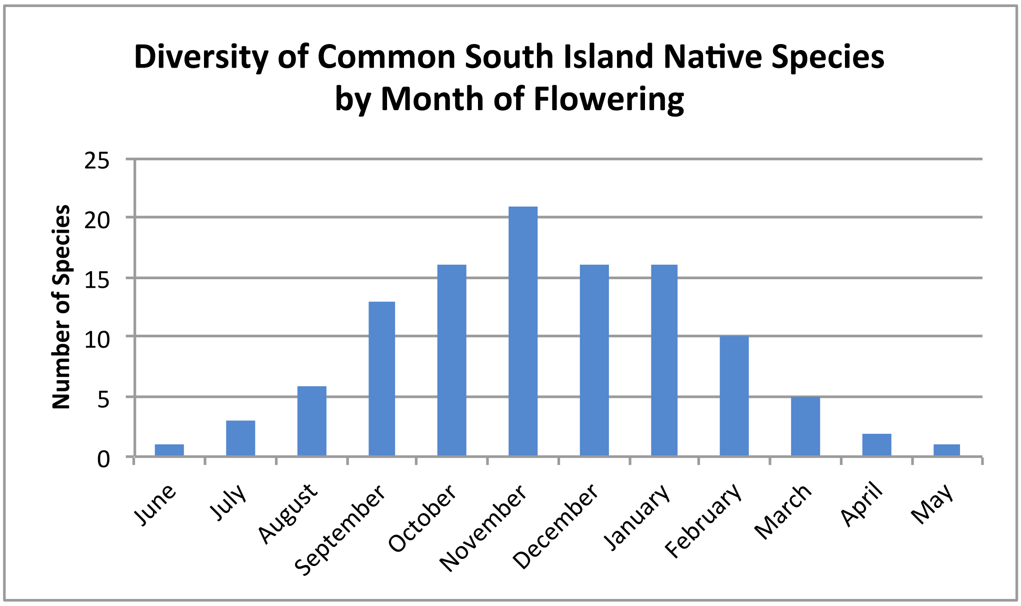


Figure 10. Species diversity chart for the most widely used South Island native bee species by month of flowering.



2.2 Exotic riparian bee plants

There is a wide range of exotic species that can be used for honey bee forage, and this handbook presents only those that have been used in Trees for Bees demonstration farm sites. Exotic species have been used on Trees for Bees demonstration farm sites for a number of purposes: amenity, including spring blossom and autumn colour; site suitability; increasing flowering diversity; economics (often fewer plants required because they are large profusely flowering trees or shrubs). Sometimes, we have needed to use exotic plants because we needed to have plants that flower abundantly at a specific time.

Willows are important riparian bee plants

Willows and poplars are a mainstay of New Zealand's riparian and land stabilisation planting. Willows are also a keystone source of bee forage during the spring population build-up of honey bee colonies. Most beekeepers rely on willows for this important role. Poplars are a significant source of propolis for honey bees, which is a resin used by bees for hive health and particularly important for bee's immune response, especially going into winter (Turcatto, et al. 2018). Both willows and poplars can be easily propagated using cuttings or poles.

Recently some willows have been declared weed species (e.g., Grey willow *(Salix cinera)* and Crack willow *(Salix fragilis)).* Grey willow is very invasive as both male and female plants exist in New Zealand and its fertile seeds are easily dispersed. Crack willow is invasive because its branches break very easily and then root elsewhere often creating a block in water courses.

Consequently, willows are being removed from a number of rivers, lakes and streams throughout New Zealand, but this is having a detrimental effect on spring build-up for beekeepers in areas where no replacement bee forage has been planted after willow removal. While it is recognised that the weed species of willow need to be removed, it is important that the role of willows in spring build-up of bee colonies is understood so that appropriate bee forage species are planted in their place.

The value of willows as a springtime pollen source for honey bees cannot be underestimated. However, most of the willow species that have been widely planted in New Zealand flower in September and October (Figure 11) so this creates a narrow window of flowering time for such a keystone species. There is often a pollen dearth following willow flowering particularly if the clover flowering is late. To expand the flowering window for bees, the willow species in the New Zealand Poplar and Willow Research Trust gene bank, a living collection in Palmerston North, were investigated (Figure 12). A large number of willow species flower earlier than September or later than October and can extend the flowering window to start in June or July and end as late as November to January. The willow species and their flowering times are listed in *Winning with Willows* (Newstrom-Lloyd et al. 2015) which can be downloaded at www.treesforbeesnz.org/information. These willows can be sourced through the Poplar and Willow Research Trust.

The willow species list in Table 5 comprises a number of tree and shrub willows that are excellent bee forage plants, some of which are also suitable as stock feed. Provided they are sited correctly further back from water courses, and brittle willows are not used adjacent to water courses, then the risk of them becoming invasive can be minimised.

To identify willow species go to the interactive LUCID key at Manaaki Whenua website https://keys.landcareresearch.co.nz/nzsalix/. A number of the species that are mentioned in the booklet "Winning with Willows" (Newstrom-Lloyd et al. 2015) have had up to date name changes which are recorded in this new LUCID key.

A recent issue in using willows has been the infestation and spread of the Giant Willow Aphid (GWA) in New Zealand (Figure 13). This aphid feeds on the sap of the willows and exudes a honeydew from late summer through to early winter, producing a melezitose sugar in the honey dew that is indigestible by honey bees. Where the level of infestation is high this can adversely impact on willow tree growth and lead to tree mortality. The honeydew attracts wasps, which leads to increased wasp populations that can then attack bee colonies often leading to colony loss. The honeydew also attracts bees who collect the honeydew, but this can taint the honey, as the sugars within this honeydew crystallises making it difficult to extract for bees and beekeepers and the flavour of the honey is unpleasant.

As a consequence, the New Zealand Poplar and Willow Research Trust is investigating the resistance of willow species to the GWA and is participating in research with Scion on introducing a biological control agent. It is hoped that the threat of GWA will be significantly reduced within the next 2-3 years (Sopow, 2018).

Exotic riparian bee plants from the Southern Hemisphere

Three groups of trees are important riparian bee plants from the Southern hemisphere. These are the hardwoods largely from Australia and South Africa – ***Acacia, Banksia*** and ***Eucalyptus*** species. While there are species within each of these groups that flower at different times throughout the year, the Trees for Bees emphasis has been on nectar-producing species for late summer and autumn. This focus addresses the limited number of plant species available in autumn in New Zealand. During late summer through autumn, both pollen and nectar sources are needed to replenish honey in the hive after the honey harvest and prepare the new young bees for over-wintering when they need to survive for several months. Some of these plant species also flower through winter and into early spring (Figure 14 and Table 6).

Used in conjunction with other species, this group provides a useful addition to the floral resources for spring and autumn bee forage. There will be other species that flower at the times you require including timber species such as E. globoidia, although eucalypts can be variable in their flowering so ask your local nursery for advice. It is important to know what type of flowering pattern each Eucalypt species has because annual flowering Eucalypts are reliable each year, but supra-annual Eucalypts are unpredictable, and some trees may not flower for many years as their normal flowering pattern. This could leave a large gap in your flowering sequence for the bees unless you have other species to fill in.

Exotic riparian bee plants from the Northern Hemisphere

There is a vast range of deciduous tree and shrub species, from forest giants to small shrubs, primarily from the North Hemisphere temperate regions. Many of these trees and shrubs can be used in riparian plantings for honey bees because they flower profusely and reliably in spring. They have been widely used in Trees for Bees demonstration farms because they fill the gap in pollen resources after the willows finish flowering and before the clover starts to flower. Many beekeepers in the South Island have called this, the October crash, because this is the typical month of pollen dearth causing problems of spring population crashes in honey bee colonies. Other species have proven useful in providing pollen resources during the early spring period when the hives are just starting to build up.

The species listed here are the most commonly and widely used but there are many other alder, maple, oak, blossom, ***Michelia, Gordonia*** and ***Viburnum*** species that will also be suitable. The species diversity of Northern Hemisphere plants that flower in the spring is high (Figure 15 and Table 7), with a number also being available for late summer and autumn.

Figure 12. Honey bee collecting willow pollen (Salix reinnii) showing the huge pollen loads and easy access to the anthers in aggregated florets along a catkin.

Figure 13. Giant Willow Aphid on willow.

Botanical Name	Common Name
Salix aegyptiaca	Musk willow
Salix aegyptiaca PN 229	
Salix alba	White willow varieties
Salix alba 'Britzensis'	
Salix alba 'Caerulea'	
Salix alba PN 357	I 2-59
Salix alba PN 361	I 8-59A
Salix alba PN 655	Lichtenvoorde
Salix alba 'Wairau'	Willows
Salix appenina	
Salix babylonica	Weeping willow
Salix candida 'Furry Ness'	Sageleaf willow
Salix candida PN 385	Furry Ness
Salix cantabria	
Salix caprea	Pussy willow, Goat willow
Salix caprea PN 233	N, Pussy willow
Salix eriocephala	Missouri willow
Salix hookeriana 'Furry Ness'	
Salix hookeriana PN 685	Furry Ness
Salix matsudana	Matsudana willow
Salix matsudana 'Tortuosa'	
Salix nigra	Black willow varieties
Salix nigra PN 733	AR 115
Salix nigra PN 734	Pryor 62-27
Salix opaca	
Salix udensis PN 283	
Salix pentandra	Laurel willow, Bay-leaf willow
Salix pentandra PN 670	Dark French
Salix purpurea	Basket willow, Purple osier
Salix purpurea PN 221	Rubra, nectar
Salix purpurea PN 382	Links Dutch, nectar
Salix reinii	Reinii willow
Salix reinii PN 688	
Salix sepulcralis Chrysocoma	Golden weeping willow
Salix triandra	Almond willow, French willow
Salix viminalis	Common Osier, Basket Willow
Salix x dasyclados PN 669	Korso, Pussy willow
Salix X dichroa (aurita x purpurea)	
Salix X *dichroa* PN 680	
Salix X forbyana (purpurea x viminalis)	
Salix X forbyana PN 305	Sessilifolia
Salix X reichardtii (caprea X cinerea)	Pussy willow
Salix X reichardtii PN 714	Muscina, Pussy Willow

Table 5. List of selected willow species from Trees for Bees research.

Botanical Name	Common Name
Acacia baileyana	Cootamundra wattle
Acacia floribunda	Sallow wattle
Banksia integrifolia	Coast banksia
Corymbia ficifolia	Red flowering gum
Eucalyptus leucoxylon Rosea	Tasmanian Yellow gum
Eucalyptus nicholii	Willow peppermint
Eucalyptus ovata	Swamp gum
Eucalyptus rodwayi	Swamp peppermint gum

Table 6. List of Acacia, Banksia and Eucalyptus species used in riparian planting.

Botanical Name	Common Name
Acer negundo	Box maple
Acer rubrum	Red maple
Alnus glutinosa v barbata	Turkish black alder
Alnus formosana	Taiwan alder
Amelanchier canadensis	Shad bush
Chaenomales japonica	Japanese quince
Chamaecytisus palmensis	Tree lucerne
Cornus mas	Cornellian dogwood
Crataegus crus-galli	Cockspur thorn
Elaeagnus pungens	Elaeagnus
Fagus sylvatica pendulata	Weeping European beech
Fraxinus ornus	Manna ash
Gordonia axillaris	Fried egg plant
Luma apiculata	Chilean myrtle
Malus sieboldii	Japanese bush crab apple
Michelia yunnanensis	Yunnan bush Michelia
Parrotia persica	Persian ironwood
Prunus mume	Japanese apricot
Prunus padus	European bird cherry
Pyrus calleryana	Chinese ornamental pear
Pseudocydonia sinensis	False quince
Quercus palustris	Pin oak
Quercus petraea	Sessile oak
Viburnum tinus	Viburnum

Table 7. List of Northern Hemisphere temperate bee forage species used in riparian planting.

Figure 11. Diversity chart for willow species by month of flowering.

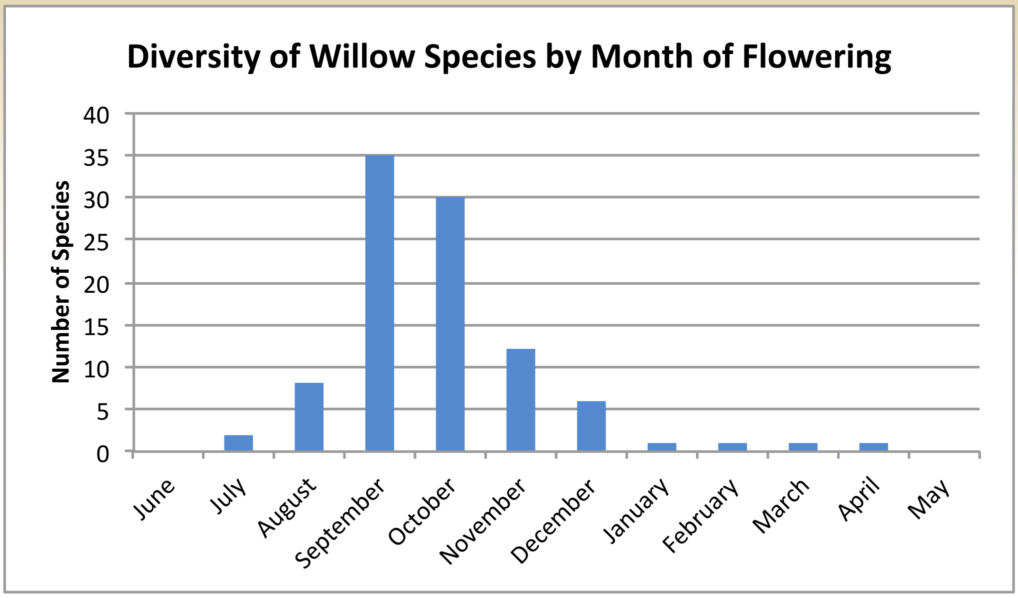


Figure 14. Species diversity chart of Acacia, Banksia and Eucalyptus species by month of flowering.

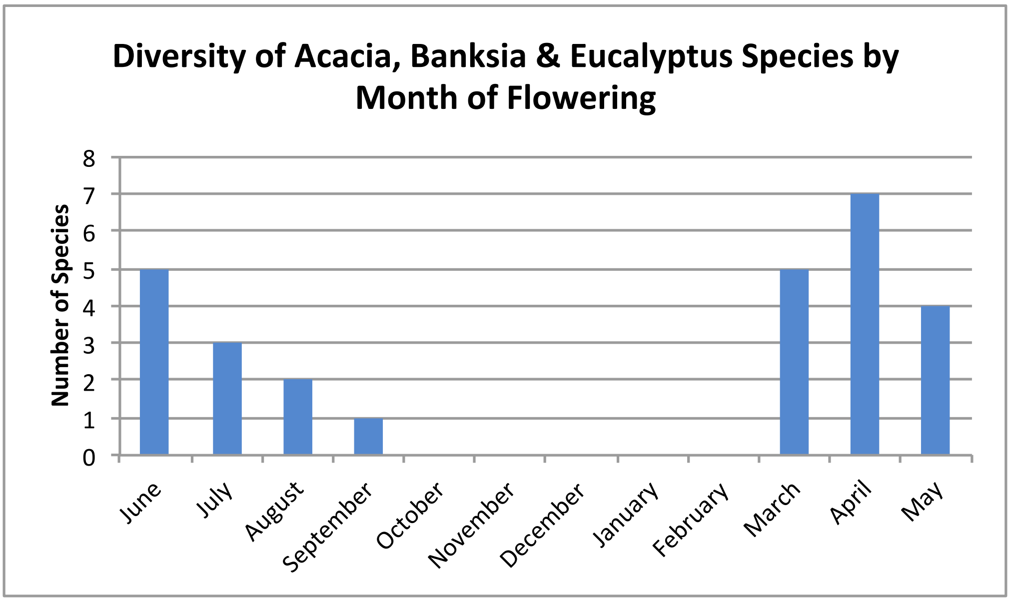
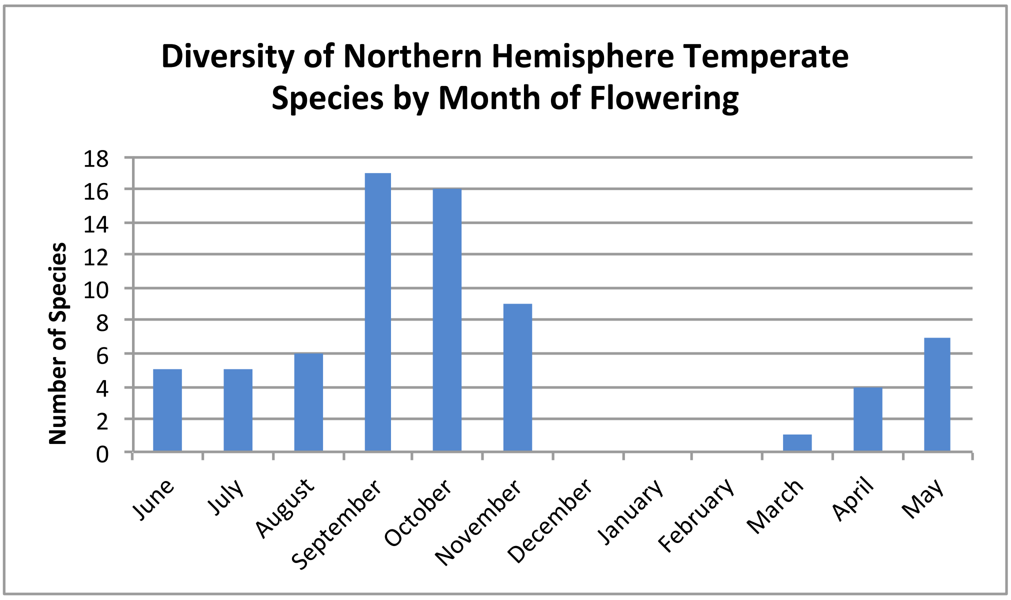


Figure 15. Species diversity chart of Northern Hemisphere temperate species by month of flowering.



3. HOW TO PLANT BEE FORAGE IN RIPARIAN ZONES

Planning and installing suitable bee forage in riparian zones requires a diverse set of skills and experience. You may need to involve a number of the following: landowner, farmer, nursery, planting advisors, and beekeeper. If your primary goal is to support honey bees year round then the focus would be on spring and autumn flowering. This applies even when the primary goal is honey harvesting (e.g., manuka plantations (McPherson and Newstrom-Lloyd 2018). Working with and consulting an experienced beekeeper in your region is a very useful first step if your goal is to service apiary sites on your own property or nearby properties or to engage in honey harvesting of any type.

Both native and exotic plant species are suitable bee forage. Native plant species are preferred where the plantation is adjacent to existing native forest, or for establishing support bee forage in native forest mānuka areas. This is due to the risk of exotic species spreading into the native forest. In addition, care should also be taken to use plants local to the area you are planting (i.e. eco-sourced). Exotic species are a suitable choice in modified environments (e.g. on farms), or where they fill a critical need and the risk of spread can be managed.

3.1 Riparian Zones

The most important part of how to plant bee forage for riparian protection is to understand the riparian zones. Riparian zones are the buffer strips along the edge of the water channel and the surrounding land. As shown in Figure 16, these can be bounded by natural or man-made structures.

Riparian zones have assumed greater significance in recent years due to their role in not only holding stream and river banks together, but also in the interception of silt and nutrient runoff. The importance of this has increased given the intensification of agricultural practices, the deterioration of water quality in some areas, and greater farmer and public awareness.

Riparian zones have also been the focus of weed removal, largely unwanted willow species. While this clearing is necessary, it is important to recognise the role these trees play in spring bee forage for our apiculture sector, and it is best to arrange replacement planting with suitable species. A further issue with the clearing of riparian zones is the expansion of farmland into the riparian zone in order to maximise pasture area, which has resulted in the loss of floral resources, habitat and biodiversity. The intensification of agriculture has also resulted in the removal of many weed sources on farms, and the replacement of a diversity of crops with monocultures. Again, this reduces the availability of floral resources for bees.

The current emphasis on planting riparian zones for soil and water protection provides an opportunity to reintroduce a diversity of floral resources, restore bee habitat, protect biodiversity and enhance ecosystem functionality in productive landscapes. The following sections shows how this can be achieved with a mix of native and exotic species, by simply including bee forage species in the planting mix for any riparian protection scheme.

The riparian zone can be further divided into flood risk areas (Figure 17). This guides the planting plan, in that you only want grasses, sedges and reeds in the **margin** because they will hold the bank together but not grow so large as to impede the water flow. This is a risk with planting flax in the margin, and is one reason why willows are being removed – they are too close to the water and impede the water flow.

The **lower bank** is where you plant flaxes, smaller shrubs like mingimingi, cabbage trees and plants that can handle occasional wet feet. Willows, especially smaller shrub willows, can be used here. The **upper bank** is where you establish a mix of shrubs and larger tree species, and those that require drier ground to grow.

Figure 16. Riparian zones.

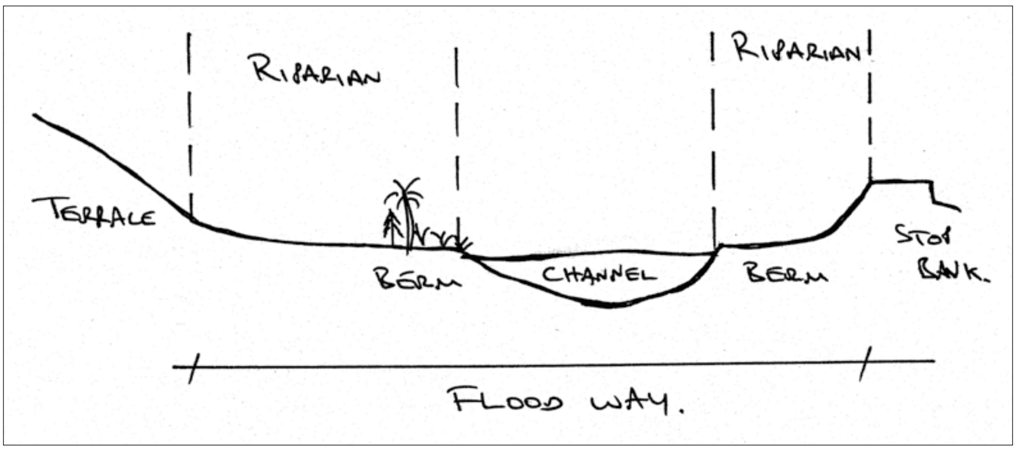
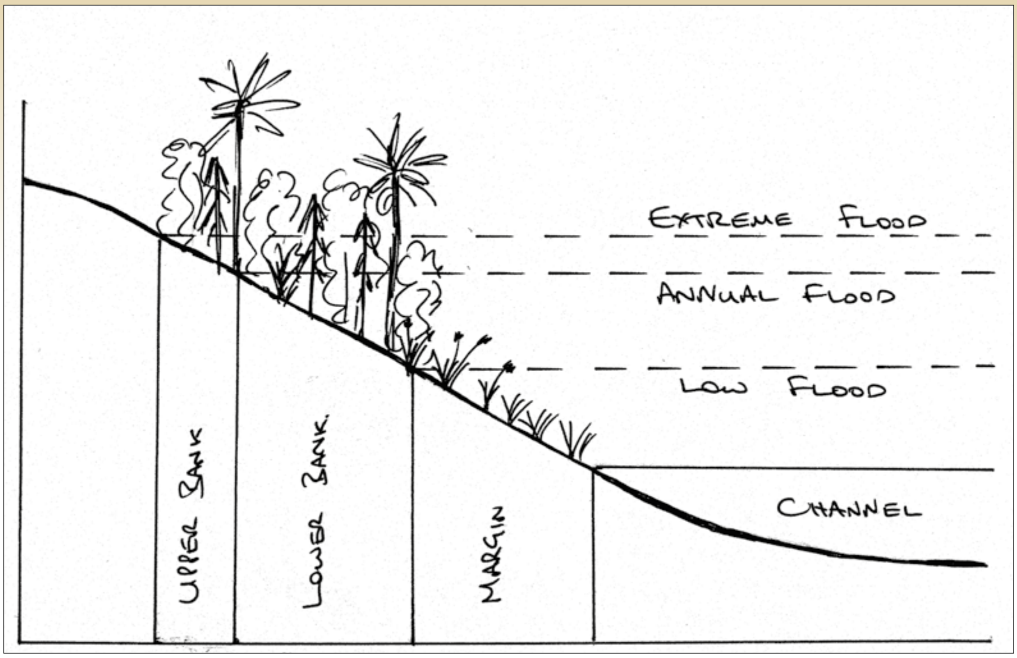


Figure 17. Riparian flood flows.



Your local regional council will have advice specific to your area on the species mix for each of these zones, which can then be checked off against the Trees for Bees plant lists. Regional councils also have information on the best willows for the different areas as does the New Zealand Poplar and Willow Trust at http://www.poplarandwillow.org.nz/.

3.2 Bee forage plant spacing

While riparian planting guidelines usually specify tight spacing of plants, the general principle for bee forage planting is to space plants to ensure they can grow to their full size at maturity and have a maximum flower surface area without being crowded. If the plants are placed too close the shaded sides of the plants will not produce flowers in species that require full or partial sun for flower bud induction and for flower bud break. Poor spacing and excessive shading and crowding results in flowers produced only at the top of the canopy. This will diminish the abundance of flowers and therefore the amount of pollen and nectar provided to the bees so it is counterproductive. Overcrowding will also increase ongoing maintenance requirements and costs due to the need to prune and/or remove overcrowded plants.

As a rule, larger trees are planted 8 to 10+ metres apart, medium trees 6 to 8m, and shrubs 3 to 4m. In general, native species tend to be planted at around 1,000 stems/ha (stems per hectare), and exotic species at anywhere from 500 to 1,000 stems/ha, depending on the mature size of the plants. Where wider spacing is used, ground cover such as low perennials and herbs can also be established among the trees and shrubs. For hedges and shelterbelts, plants are spaced around 1.5m apart in a single row, or two offset rows with the plants in each row 3m apart. Specific designs are shown at www.treesforbeesnz.org/information. Unless planting a hedge/shelterbelt, try to avoid planting trees in straight rows. Stagger them a little to help make it look more natural.

3.3 Bee forage plant protection weeds and pests

Animal pest control prior to planting is critical for successful bee forage establishment, and as noted earlier this also extends to ensuring livestock are excluded from the planting area. Key pests include deer, goats, possums, hares and rabbits, and it only takes a small number of any of these to wreak extensive damage. Pests such as possums feed on the most palatable plants in descending order and when they are removed, this can have a huge impact on nectar and pollen resources (Mowbray, 2002). A pre-plant shooting, trapping and/or poisoning programme is essential to ensure pest numbers are as low as possible. Ongoing pest control is also important to keep pest numbers under check.

Where there are small numbers of bee forage species being planted, individual tree guards can protect seedlings from browsing rabbits, hares and possums. Tree guards can help keep pests away from the plants and come in a range of styles and sizes. Small plastic sleeve/tube guards are suited to small shrubs as well as tall seedlings and poles. The sleeves also protect the plant from any spray drift when applying herbicides for weed control. For larger specimen trees, reinforcing steel guards or wooden tree guards can be constructed to keep stock and larger pest animals from damaging the plants.

As with pest control, weed control is essential for the successful establishment of bee forage support planting and the key to success is good weed control prior to and at the time of planting to give the seedlings the best chance of survival and fast early growth. If this is achieved, then the bee forage plants should keep ahead of any weed species, although subsequent weed control may be required and can be assessed on a case by case basis.

Weed control options for bee forage species include grazing the site before planting and/or a pre-plant weed spray. Blanket spraying is not appropriate near waterways as you risk spray drift into the waterway and retaining ground cover assists interception of nutrients and sediment runoff. Therefore, spot spraying is recommended as a pre-plant and (if required) post-plant treatment. Retaining rank pasture grasses as a weedy ground cover in the riparian zone while the riparian bee forage plants are getting established is also a viable option. By not grazing the site before planting and simply spraying each planting spot, the rank grasses will not compete as much for moisture as rapidly growing grasses after grazing, and they will also provide shelter and protection to newly established plants. Applying a mulch around the bee forage plant following planting will assist weed control, and there is also the option of sowing a ground cover bee forage species (e.g. borage, phacelia, and some clover species).

3.4 Bee forage plantation establishment timing and costs

The time to plant bee forage is ideally in winter, especially for bare-rooted plants, although mānuka and other native species can be successfully established in autumn if pest control is good – otherwise the pests will see these as a useful forage source over winter. Autumn planting allows roots to start growing before winter so that the plants are able to take advantage of early spring growth. Leaving a cover of rank grasses can help hide the bee forage plants from pests as mentioned above. Spring establishment of root trainer or bagged plants is also feasible, although you run the risk of plants not being properly established ahead of a potentially dry summer.

For cultivation and establishment of bee forage plants, standard planting practices are followed. Use your spade to remove the grass turf where you want to plant your shrub/tree. Open up a hole slightly larger than the plant's roots, and make sure the soil around the edge and the bottom of the hole is loose otherwise the plants roots can be constrained on the sides.

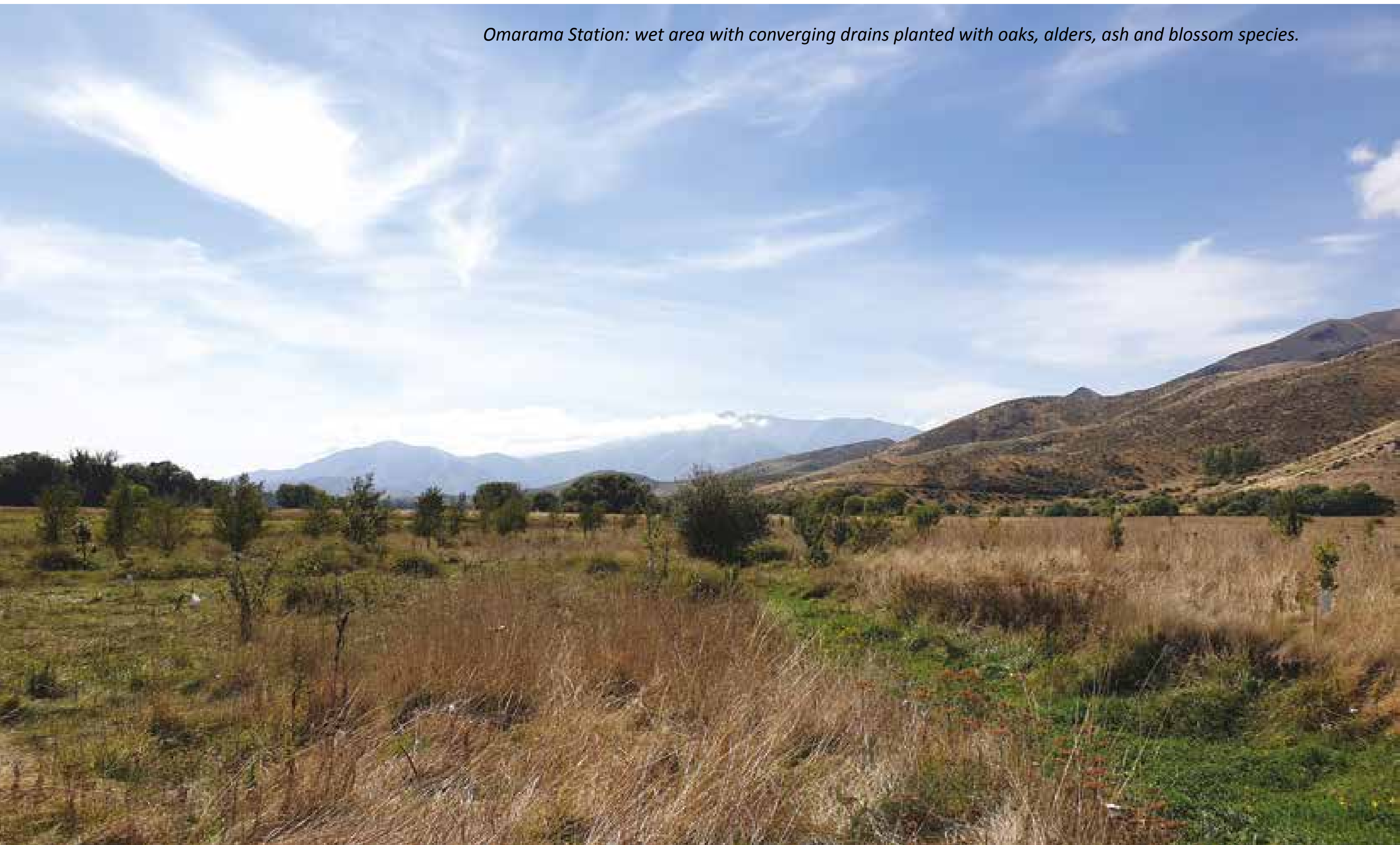
Place your plant in the hole and place the soil back around it. Make sure the plant isn't placed too deeply - lift it up to ground level or even a slightly raised mound if required. Firm the soil around the plant with hands/foot to keep it stable, but don't stamp around the plants as you can damage the roots. Do not leave an air pocket around the roots however.

Use a stake if required to assist plant stability for the first couple of years. These should be at right angles to the prevailing wind and allow the plant to move slightly so that its roots can strengthen from that movement.

Bagged and root trainer plants include a slow-release fertiliser, which will give one season of support and will help get the plants established. Bare-rooted seedlings do not include fertiliser. Depending on the plants purchased and the number to be established, additional slow release fertiliser tabs can be used.

The cost of establishing bee forage species depends on the number, type and size of plant being established, and whether they require tree guards, fertiliser tabs and pre-plant spraying. For native species, the cost per plant established is typically $5 to $6 per plant, including the cost of planting, which at 1,000 stems/ha is $5,000 to $6,000/ha. For exotic species, the cost per plant established for smaller grade plants is typically $5 to $15 per plant, and assuming 500 to 1,000 stems/ha and an average cost of $10 per plant this would total to $5,000 to $10,000/ha. Therefore, as a rule of thumb you should be budgeting on $5,000 to S10,000/ha for your bee forage planting and considering a balance of native and exotic species to meet your forage requirements in a cost-effective manner.

Exotic tree species such as tulip trees, oaks and maples have the advantage of providing significant amounts of nectar and pollen in time as they mature and offer a vertical dimension for bee forage. Bear in mind that the area required for riparian planting can be quite small. For example, a 100m length of riparian zone with a 5m wide strip of planting either side of the steam is 0.1 ha, and 10m either side is 0.2 ha.



Omarama Station: wet area with converging drains planted with oaks, alders, ash and blossom species.

4. RIPARIAN BEE PLANTATIONS FOR APIARY SITES

Riparian planting can be for many purposes as discussed in the introduction. Because a riparian plantation can be a good source of spring and autumn bee forage, it can also be an ideal site where an apiary can be established nearby (Figure 18). If the purpose of the riparian plantation is to directly benefit honey bees in apiary sites on or near the riparian plantation then a number of factors need to be considered for maximising the benefit to the bees depending on what the goals of the apiaries may be.

Figure 18 – Hives located adjacent to native species riparian zone planting at Callaghan Farm, Mid Canterbury.

The most important factor to consider is the level of your beekeeper's skills in terms of past experience in beekeeping in your local region where the climatic changes, weather patterns, and existing local flowering times and nectar and pollen sources are well understood. Decisions on whether to establish an apiary site and identifying a good site in terms of protection and warmth for the bees can be more important than the distance to the target crop and bee forage areas. Having a skilled and experienced beekeeper who understands the local climate and flowering times and how to manage the hives in the region is crucial first step in identifying and establishing the location of apiary sites if there is to be one.

Other factors include whether the apiaries are to be stationary or moved to target crop sites or to spring build-up sites or over-wintering sites. If they are seasonally relocated off the property for honey production or pollination, then you need to consider over what period of time the hives will be on the property, as this will influence the planned flowering times needed for the bee forage to support bees when they are on the property.

Specific requirements for apiary locations need to be considered first, so that any protection planting for the apiary and early spring or autumn forage planting can be located appropriately. Apiaries can be permanent (stationary or residential apiaries) or they may be seasonal (alternating or migrating apiaries). Each apiary site needs to combine the best alternatives for the relevant seasons such as for spring and summer pollination, summer honey flow, spring and autumn forage supply and winter rest period.

The residential system has an advantage because it eliminates moving the bees which carries a labour cost and can disrupt the bee colonies. In some cases, however, alternating apiary sites is mandated because the bees need to avoid harsh microclimates in some seasons (for example, too cold in the winter, too dry or windy in the autumn). In other cases, moving bees for one season may be required if accompanying land use or farm operations would harm bees or bees would interfere with farm operations, for example, pesticide use or nuisance to human activities nearby. Each case will be different, and the logistics are best worked out in collaboration between the relevant beekeeper (or an experienced/local beekeeper) and the landowner at the site(s).

4.1 Locating apiary sites

In general, the following seven factors (in descending order of importance) are critical for locating a good apiary site in addition to the site having good levels of bee forage (diverse and extended flowering) as well as no competition from other apiaries that are located too close within the foraging area. As noted above, locating an apiary site within a farming operation should also take into consideration the needs of the other land users at the site, especially cropping that uses pesticides, animal husbandry operations and human movements.

- Shelter from cold and prevailing winds.
- Sun for much of the day including low angle sunlight in winter for over wintering sites.
- Good safe access by beekeepers truck.
- A site elevated away from potential flooding.
- Good air drainage to avoid cold air sinks and excessive shading.
- Fresh water for bees available.
- Lack of nuisance to stock or people by locating away from heavily used areas.

All of these factors are rarely found in an unmodified site so consideration should be given in planning to engineer and adapt any given site to take into account all of these seven factors that may not be ideal or are missing.

4.2 Bee forage location and composition

Once the beekeeper and landowner have decided where to place the apiary site, then the location of the bee forage plants can be determined. Establishing bee forage to support the colonies in your apiaries needs to follow the phases of the bee colony's demand for pollen and nectar through the year (Appendix). Many beekeepers are planting year-round forage to supply fresh natural pollen and nectar because it is the least expensive and best source of nutrition for the bees.

It is best to locate bee forage plants to be installed as near to the apiary site as possible especially for the key sources for autumn and early spring forage. Apiary sites need to be sheltered from the prevailing wind, and open to the north so they receive good daily sun, particularly in winter. Therefore at least some of the bee forage shelter species for the prevailing wind should be evergreen, and these can be tall species if they are located to the south of the apiary. To the north any taller plants should be located further away, and ideally be deciduous to reduce the risk of winter shading. Smaller shrub and herb species can be used as hedging closer to the hives, leaving enough space for access and vehicle movement to service the hives.

Planting both the late summer/autumn and early spring flowering species closest to the apiary site will promote colony survival through winter and into early spring because the distance to the bee forage is short. During these seasons, the days are shorter and the weather can be more variable with sudden changes to harsh conditions that compromise the bee's return flight to the hive. It is best to keep the bees foraging much closer to the hive so that they can maximise the number of trips to and from the hive and minimise the risk of being caught out by a weather change that could mean they lose their way back to the hive or die before they can reach the hive.

It is always important to place the plants of a given bee forage species in large clusters or mass plantings because this will maximise the size of the flowering patch making it more attractive to the bees. A large cluster of the same plant species improves not only the bee's foraging efficiency but also maximizes the chance that the flower patch will be discovered by the bees. Larger size trees that have more flowering area can be interplanted at wider spacing amongst mass planted shrub species.

When determining the composition of bee forage, it is important to consider a number of other factors, including landowner pollination requirements (e.g. clover pasture, fruit/vegetable crops, home orchard/garden), and other broader environmental goals such as supporting native pollinators (solitary bees, moths, butterflies, hover flies etc.), enhancing biodiversity, restoring ecosystem function and increasing habitat area in the productive landscape. This includes the extent and type of any exotic bee forage species and native bush on the property or nearby, which will influence the planned flowering period to support bees on the property, and whether consideration should be given to secondary benefits such as fruit/seeds for birds.

4.3 Planning bee forage based on the flowering calendar

Pollen and nectar resources needed by honey bees

Management of floral resources to support hive development is critical for all beekeepers. This covers not only spring build-up, but also managing flowering resources during the pollination services and honey harvesting seasons, and enabling colony recovery in autumn in preparation for over-wintering.

The annual bee forage budget has been estimated by Seeley (1995) who reports that the annual hive requirements are approximately as follows:

- **20 kg pollen** (pre-digested by nurse bees fed to queen, brood, and other workers)
- **120 kg nectar** (energy for all life stages, stored as honey, produce wax -- 5 gm nectar gives 1 gm wax)
- **25 litres water** (evaporative cooling of hive and vital for nurse bees for royal jelly)

This may seem like an overwhelming amount of floral resources when you consider the size of most flowers and how much pollen and nectar they produce. To optimise or even maximize the floral resources from your plantation it is important to understand the supply and demand cycle for a bee colony (see Appendix).

Proceeding in a methodical manner to balance the bee forage plantation to meet the pollen and nectar needs of honey bee colonies will give the best results. The Trees for Bees NZ team has developed and is using several tools based on the flowering calendar. These tools can be used to assist with planning a planting list for strategic bee forage plantations so that they will also meet the beekeeper's and landowner's goals. These tools can be used to assess existing floral resources or to plan planting programmes. For definitions of each tool see the Glossary at the end of the Appendix. The four tools are used in sequence starting with the flowering calendar, the species diversity chart, the bee forage profile and finally the optional annual bee forage budget. Working with these tools is an iterative process while you adjust the final planting list to best serve your scenario for planting.

The basic flowering calendar

The first step is to create a **flowering calendar,** which is a list of species/cultivars and the months in which they typically start and end flowering. The rows of the flowering calendar are the list of bee forage species and the columns are the months of the year. For each row, insert the number one into each cell to indicate which months the plant species is typically in flower as shown in Figures 19 and 20. The cells can be blank or have a zero to indicate the species is not typically in flower in a given month.

The flowering calendars illustrated in Figures 19 and 20 show only some examples of native plant bee forage species but a more complete species list of bee plants can be downloaded from www.treesforbeesnz.org/information. Our online candidate species list is continually updated by the Trees for Bees NZ team and contains over 300 species. The flowering times shown in Figures 19 and 20 are national level flowering times not local or regional. To refine them by adjusting them to your area requires local knowledge – check with a local beekeeper or nurseries to fill any gaps in your knowledge of local flowering times. Many local beekeepers, based on experience, are familiar with the general flowering times of the most important bee plants. This is how they assess the potential floral resources for an apiary site.

Biostatus	Botanical Name	Common Name	Winter/Early Spring				Spring/Early Summer		Summer				Early Winter	
			June	July	August	September	October	November	December	January	February	March	April	May
Native	*Fuchsia excorticata*	Tree fuchsia	1	1	1	1	1	1	1	1				
Native	*Melicytus lanceolatus*	Narrow-leaved mahoe	1	1	1	1	1	1	1					
Native	*Pseudopanax arboreus*	Five-finger	1	1	1									
Native	*Metrosideros carminea*	Crimson rata			1	1	1							
Native	*Leptospermum*	Manuka				1	1	1	1	1	1	1		
Native	*Kunzea ericoides*	Kānuka				1	1	1	1	1	1			
Native	*Pittosporum umbellatum*	Haekaro				1	1	1	1	1				
Native	*Pittosporum ralphii*	Ralph's Kohuhu	x			1	1	1	1	x	x	x	x	x
Native	*Pittosporum crassifolium*	Karo				1	1	1	1					
Native	*Weinmannia silvicola*	Kāmahi				1	1	1	1					
Native	*Metrosideros diffusa*	Rata vines					1	1	1	1				
Native	*Olearia furfuracea*	Tanguru					1	1	1	1				
Native	*Pittosporum eugenioides*	Lemonwood					1	1	1					
Native	*Knightia excelsa*	Rewarewa					1	1	1					
Native	*Cordyline australis*	Cabbage tree					1	1	1					
Native	*Carpodetus serratus*	Marble leaf						1	1	1	1	1		
Native	*Pennantia corymbosa*	Kahikōmako						1	1	1	1			
Native	*Melicytus ramiflorus*	Whiteywood						1	1	1	1			
Native	*Metrosideros umbellata*	Southern rata						1	1	1	x	x		
Native	*Ixerba brexioides*	Tāwari						1	1	1				
Native	*Metrosideros robusta*	Northern rata						1	1	1				
Native	*Phormium tenax*	NZ flax						1	1					

Figure 19. A flowering calendar for a list of selected candidate native species with flowering time data derived from the national level flowering times. Mānuka and kānuka are highlighted in yellow. Five Finger is an excellent choice as a spring build up plant.

Biostatus	Botanical Name	Common Name	Winter/Early Spring				Spring/Early Summer		Summer				Early Winter	
			June	July	August	September	October	November	December	January	February	March	April	May
Native	*Carpodetus serratus*	Marble leaf						1	1	1	1	1		
Native	*Pennantia corymbosa*	Kahikōmako						1	1	1	1			
Native	*Melicytus ramiflorus*	Whiteywood						1	1	1	1			
Native	*Metrosideros umbellata*	Southern rata						1	1	1	x	x		
Native	*Ixerba brexioides*	Tāwari						1	1	1				
Native	*Metrosideros robusta*	Northern rata						1	1	1				
Native	*Phormium tenax*	NZ flax						1	1					
Native	*Hoheria angustifolia*	Narrow-leaved lacebark							1	1	1	1		
Native	*Metrosideros albiflora*	Large white rata							1	1	1	1		
Native	*Metrosideros excelsa*	Pōhutukawa							1	1				
Native	*Weinmannia racemosa*	Kāmahi							1	1				
Native	*Pseudopanax crassifolius*	Hoheka								1	1	1	1	
Native	*Metrosideros perforata*	Small white rata								1	1	1		
Native	*Hebe salicifolia*	Koromiko								1	1	x	x	
Native	*Metrosideros fulgens*	Scarlet rata	1								1	1	1	1
Native	*Schefflera digitata*	Seven-finger									1	1		
Native	*Dysoxylum spectabile*	Kohekohe	1									1	1	1
Native	*Olearia paniculata*	Akepiro										1	1	1
Native	*Hoheria populnea*	Lacebark	x									1	1	x
	Total species flowering each month		**5**	**3**	**4**	**9**	**14**	**20**	**24**	**19**	**12**	**11**	**5**	**3**

Figure 20. A flowering calendar for a list of selected candidate native species with flowering time data derived from the national level flowering times. Lacebark is an excellent choice for an autumn flowering pollen and nectar producing plant.

The flowering calendar for the proposed honey bee forage is best arranged so that it starts in winter in June when the bees are mostly resting (at least in cold climates). This allows us to visualise the pollen and nectar demand for the colony in the species diversity chart and bee forage profile to show the building up phase in spring and the winding down phase in autumn as shown in the Appendix in Figure 32.

We use the flowering calendar to select candidate bee forage species to plant, based on identifying the plants that flower during the desired period and placing them into the species diversity chart. Selecting candidate plants is an iterative process which involves filtering and adjusting the list based on flowering times, attractiveness to bees, value of pollen and/or nectar, and multi-functional purposes for the use of the plant and the growing conditions at the proposed site (frost, snow, drought, wind etc.). This process benefits enormously from seeking advice from diverse sources such as farm planting advisers, nurseries, beekeepers and other plant or beekeeping experts who are skilled in landscaping, plant knowledge and beekeeping.

The species diversity chart

The second step is to create the **species diversity chart** based on the flowering calendar. The species diversity chart is the list of plants selected from the flowering calendar for a given plantation site. It is represented in graphical form as the total number of species flowering in each month of the year as shown in the examples in Figures 6 to 15. This chart is created to ensure, as far as possible, that there is sufficient flowering diversity in each month of the year. This is an important step because adequate diversity creates a buffer in case any given plant species fails to flower in a given year.

The species diversity chart is used to visualise gaps in the floral resources over the year as shown in the hypothetical examples in Figures 21 and 22. To make sure the bees will attend to your target plants at the right time (e.g., for honey harvest of pollination services) it is important to ensure as far as possible that no candidate species selected will flower at the same time and therefore compete with the target species at the site. This means you will need to have general knowledge about when the target species will most likely be in flower, and this will vary depending on species and location. Although the flowering start date may shift from year to year it will still be within the range of a few weeks within a season and usually if one species is early or late in a given year the accompanying species will also be late or early (in general but New Zealand has exceptions).

For the species diversity chart, the goal is to have at least ten species flowering each month, except in winter when the bees are resting. This diversity provides "backup" species in case some plants scheduled to flower in a given month sometimes start flowering at a different time than expected. It also provides alternative species if some species skip flowering for one or many years or become diseased or die. In addition, a greater diversity of plant species provides better nutrition for the bees (Di Pasquale et al., 2013). If it is not possible to reach ten species per month, then at least maximise the number of species per month as much as you are able.

The species diversity chart can be used to analyse the pre-existing species at the site or work on the proposed species that you are planning to plant. Information on the pre-existing list of species at the site and their flowering times is often not available. In most cases, there are too many unknowns about the identity of the plants and their flowering times or there are too many species to enumerate in the time available so species diversity charts of pre-existing species are often not used.

The bee forage profile

The third step is to create a **bee forage profile,** which shows the number of plants flowering each month. The bee forage profile can be for existing floral resources and for new planting, and is used to estimate the number of plants desired for each species. The bee forage profile is based on the species diversity chart except that we insert the number of plants for each species. This is achieved by either directly replacing the number 1 in each cell with the number of plants for that species, or by multiplying the species diversity chart cell entries by the number of plants for each species to create a second chart. The column totals will now reflect how many plants are flowering in each month, and this can be compared with the desired profile required for your bee forage. To manipulate the shape of the bee forage profile simply increase or decrease the numbers of plants for each species accordingly. The bee forage profile will also reveal any large gaps in your existing floral resources or proposed candidate list and will help guide the shape of the bee forage profile for the proposed bee forage plantation.

To Illustrate how to interpret a bee forage profile; a hypothetical example is given in Figure 21 where a sudden pollen deficit occurs in October in the existing flora. This "October crash" is a well-known pollen dearth time that was a widespread problem in both the North and South Islands where farm biodiversity was extremely low, resulting in pollen shortages after the willows finished flowering but before the clover started flowering. Our Tree for Bees research resolved this problem on our demonstration farms by installing maples, oaks, and ash trees among other October flowering species, with the beekeepers reporting improved hive performance. Such farm trees flowering in October also provided shade and shelter for livestock and amenity which demonstrates how to use multi-function plants that also feed the bees.

The October crash with the springtime pollen dearth was readily resolved, but it has been much more difficult to resolve cases of pollen or nectar dearth in autumn as shown in the next hypothetical example in Figure 22. The problem here is that our New Zealand flora for both native and exotic plants has very few candidate plants flowering in autumn. Nevertheless, we have discovered some reliable autumn flowering species such as lacebark ***(Hoheria populnea, H. sexstylosa),*** koromiko ***(Hebe stricta),*** and akiraho ***(Olearia paniculata)*** among others. These can be planted in high numbers to provide enough floral resources for autumn as it is often difficult to reach a high diversity score per month for autumn.

To work towards the best shape for a proposed bee forage profile, the goal is to have few candidate plants flowering in winter (June/July) when the bees should be resting if it is cold, and then rapidly increasing flower availability (especially

Figure 21. Hypothetical example of a Bee Forage Profile: This bee forage profile chart shows the number of plants from different species that are flowering in each month of the year for one foraging area. This bee forage profile illustrates a serious deficit in October just after two months of spring build-up have occurred.

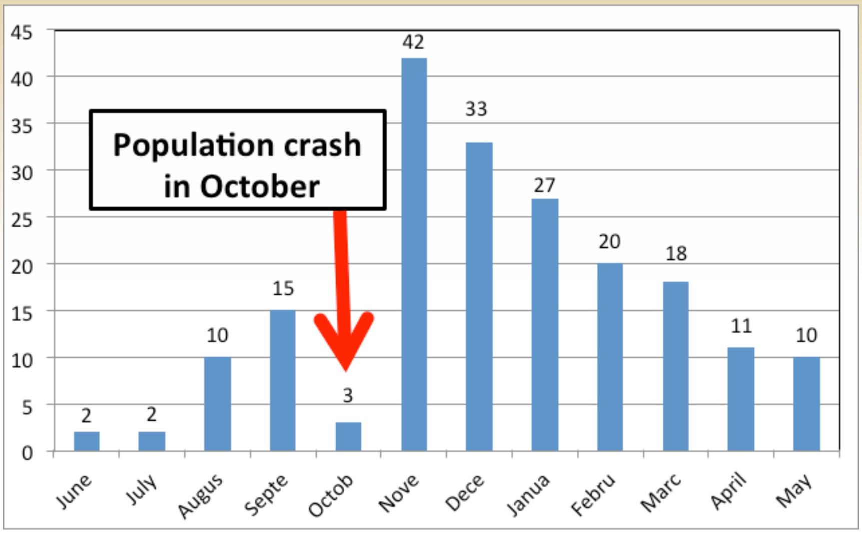
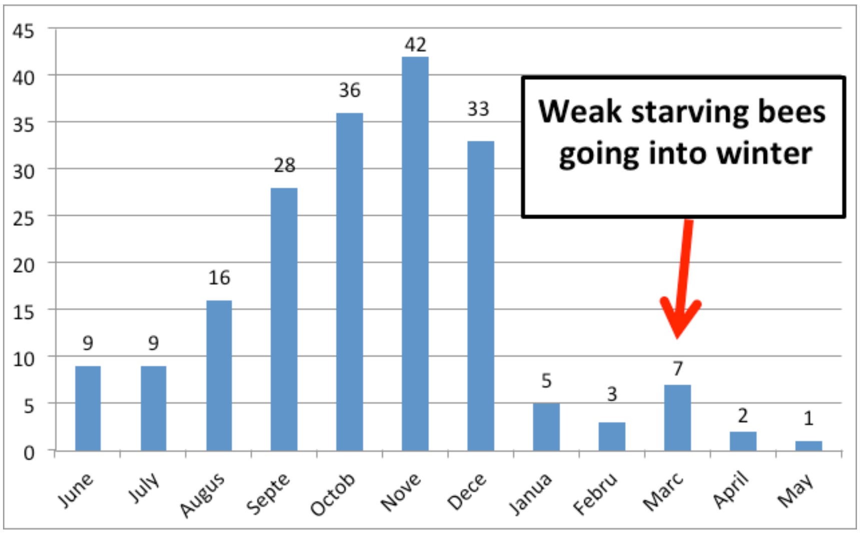


Figure 22. Hypothetical example of a Bee Forage Profile: This bee forage profile chart shows the number of plants from different species that are flowering in each month of the year for one foraging area. This bee forage profile illustrates a serious deficit in late summer through autumn when the winter bees are developing.



for pollen) from August to November for spring build-up of the colonies. Flowering plant numbers for a plantation would then drop back over summer while bees are on pollination services and/or honey harvesting. This is important because, for example, when the mānuka honey flow is on (see yellow highlighted row for mānuka in Figure 19), it is undesirable to have any competing nectar sources, although the bees need a pollen source as they do not prefer the mānuka pollen and will often go to clover and other pasture species for pollen during the flow. Therefore, any candidate plants flowering at this time are selected to provide good pollen with very little nectar, for example some of the native *Coprosma* and *Olearia* species. Finally, in late summer to autumn, the candidate flowering plant numbers are built up again to prepare the bees for winter, with good nectar sources important after the honey frames have been removed from the hives.

The annual bee forage budget

A fourth step, creating an **annual bee forage budget,** is required if you need to look at a number of sites that are designed to service one or more apiary sites. This step involves summing over two or more bee forage profiles to obtain a cumulative total of the plants available to the apiary. It may be summing over several subsites such as riparian and shelterbelt planting in a large area, even as large as a 3 to 5 km foraging area (see Appendix), or it may be a question of combining two bee forage profiles – one for the pre-existing floral resources (in case you have this data) and the other for the proposed planting. The process of combining two or more bee forage profiles is similar to creating a simple bee forage profile shown in step three above.

The following case study shown in Figures 23 to 25 is taken from a Trees or Bees demonstration plantation established on a Hawkes Bay sheep and beef farm. This example shows how to use the tools to design bee forage planting to support mānuka plantation establishment, where the bee forage plants were established in riparian zones and other areas where the mānuka wasn't established. The expected flowering time for the mānuka is late January/February. In this situation, there is existing native species riparian planting with predominantly spring and summer flowering species, but with insufficient autumn flowering species. A bee forage profile for an adjacent riparian area was designed to address these gaps, so that the overall annual bee forage budget was more balanced.

Existing Plantation Bee Forage Profile. The key issues here are the high number of plants flowering in January, and the almost total lack of late summer/ autumn flowering species. The large number of species flowering during the mānuka season may be in competition with the mānuka flowers so no more summer flowering plants are desired. The existing species will supply pollen and hopefully not too much nectar such that the mānuka nectar harvest becomes diluted.

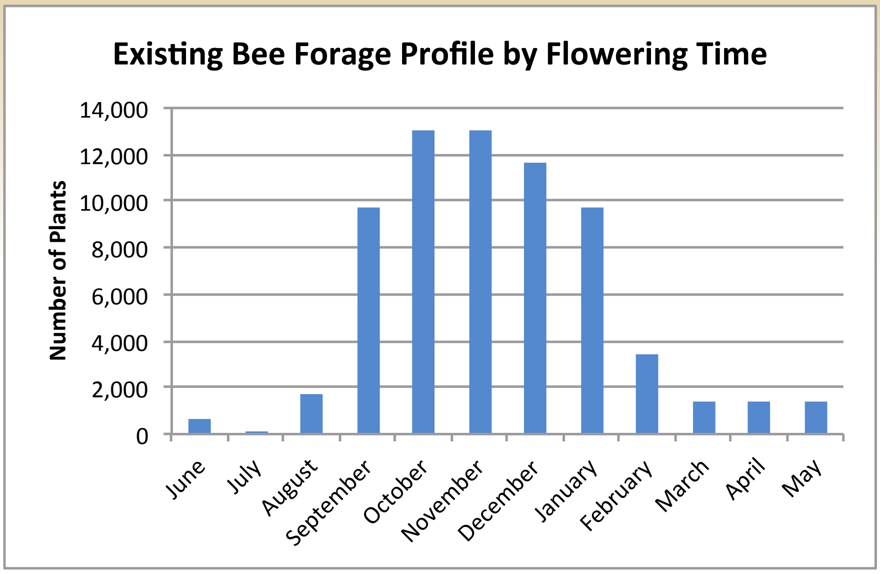


Figure 23. Case Study: bee forage profile for existing riparian planting.

Proposed Plantation Bee Forage Profile. To reshape the flowering calendar profile, Trees for Bees focussed on spring, late summer and autumn-flowering species, both in terms of number of species, but in particular with the number of later summer and autumn flowering plants, including exotic species. The shape of the flowering calendar profile is therefore "adjusted" by using a larger number of plants for the species flowering at the critical times of spring and autumn.

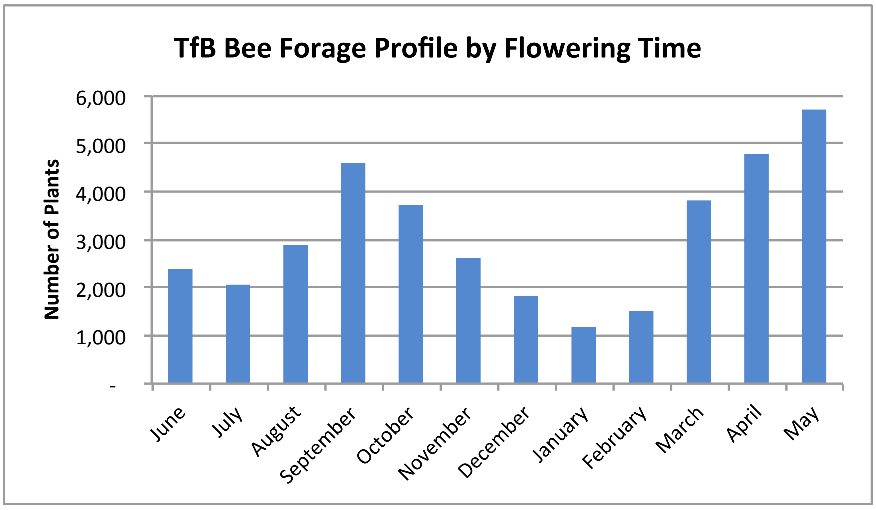


Figure 24. Case Study: bee forage profile for proposed planting.

Cumulative Total of Both Existing and Proposed Bee Forage Profile. The combined effect of the riparian and bee forage profiles is to have a more balanced profile to match the bee demand, with strong spring and summer build-up, dropping off in February, and then an increase in flowering a gradual build up from March to May in autumn.

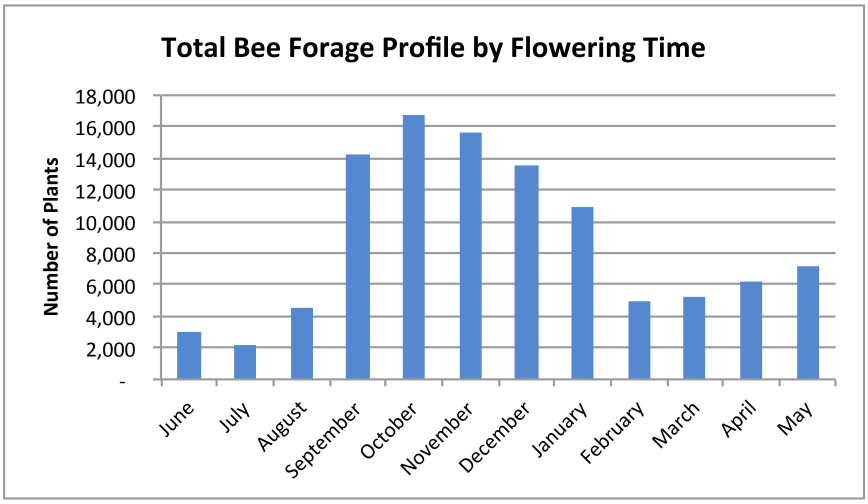


Figure 25. Case Study: bee forage profile for combined plantings of both pre-existing and proposed.

5 RIPARIAN BEE PLANTATION CASE STUDIES

5.1 Kintail Honey, Hawke's Bay

As an important provider of pollination services and with a sizeable honey operation, it is important for Kintail Honey to have control over their queen-raising and over-wintering sites. This is being achieved on their home farm at Takapau.

Riparian planting at Kintail Honey has focussed on replanting willows removed along the river margin with a wider range of cultivars from the Trees for Bees research programme. This provides a strong framework for spring build-up, and this is balanced by a wider range of spring, summer and autumn bee forage throughout the farm (Figure 26). Cuttings of tree and shrub willows were established at 5m centres along the river margin.

This is part of an ongoing planting programme with Kintail, starting in 2013 to design and implement planting year-round bee forage to improve apiary health and vigour, reduce dependence on supplementary feeds, and support the ongoing farming operations (McPherson, 2018). In addition to the riparian planting, bee forage has also been established as large specimen trees for paddock shade and shelter; replacing pine and cypress shelterbelts and woodlots with bee forage species; fencing and planting unproductive escarpments; and establishing avenues along the farm laneways. By establishing a number of plants each year, Kintail have been able to do this work in a cost-effective manner, using winter downtime for planting labour.

Now approaching the sixth year of planting, Kintail is reporting improvement in their apiaries with increased hive numbers and greater bee colony vigour. They are observing bees actively foraging on the established bee plants. Many of the species started flowering in the first and second year and many of the trees have reached a good size already. A list of the most successful species is given in Tables 8 and 9.

Figure 26 – Kintail Honey Farm: Riparian zone in the background. Senescent willows cleared and replaced with trees for Bees willows. Additional bee forage established in tree guards in the foreground to support the nearby hives.

Table 8 – Kintail Honey Farm: Species list of the most successful native and exotic bee forage plants established at Kintail Honey.

Location	Botanical Name	Common Name
Specimens	*Acacia baileyana*	Cootamundra wattle
	Acer negundo	Box elder
	Acer platanoides	Norway maple
	Acer saccharum	Sugar maple
	Aesculus x carnea	Horse chestnut
	Banksia integrifolia	Coast banksia
	Eucalyptus leucoxylon Rosea	Tasmanian Yellow Gum
	Fraxinus americana	American white ash
	Fraxinus ornus	Manna ash
	Liriodendron tulipifera	Tulip tree
	Magnolia campbellii alba	White Campbell's magnolia
	Magnolia loebneri Merril	Magnolia
	Parrotia persica	Persian Ironwood
	Prunus subhirtella 'autumnalis rosea'	Autumnalis cherry
	Prunus yedoensis	Yoshino cherry
	Quercus coccinea	Scarlet oak
	Quercus petraea x robur	Hybrid English oak
Shrubs	*Acacia floribunda*	Sallow wattle
	Acacia pravissima	Ovens wattle
	Camellia sasanqua Setsugekka	Camellia Setsugekka
	Chaenomales japonica	Japanese quince
	Malus sieboldii	Japanese bush crab apple
	Michelia yunnanensis	Yunnan michelia
	Pseudocydonia sinensis	False quince
Ground cover	*Lavender*	Lavender
	Rosmarinus Tuscan blue	Rosemary
Native	*Coprosma grandifolia*	Kanono
	Coprosma robusta	Karamu
	Cordyline australis	Cabbage tree
	Hebe stricta	Koromiko
	Hoheria populnea	Houhere, lacebark
	Hoheria sexstylosa	lacebark
	Olearia paniculata	Akiraho, Golden akeake
	Olearia solandri	Coastal tree daisy
	Olearia traversii	Chatham Is akeake
	Pittosporum eugenoides	Tarata, lemonwood
	Pittosporum tenuifolium	Kohuhu, Black matipo
	Pseudopanax arboreus	Five finger
	Sophora tetraptera	Nth Is kowhai

Table 9 – Kintail Honey Farm: Species list of the Trees for Bees willow plants established at Kintail Honey.

Botanical Name	Genotype	Reg No
S. aegyptiaca L. (=medemii Boiss.)		PN 229
S. alba L.	I 2-59	PN 357
S. alba L.	I 8-59A	PN 361
S. alba L.	Lichtenvoorde	PN 655
S. candida Fluegge ex Willd.(=Furry Ness)	Furry Ness	PN 385
S. caprea L.	N	PN 233
S. eriocephala Michx.	Americana	PN 376
S. hookeriana Barratt (= candida Furry Ness)	Furry Ness	PN 685
S. lasiolepis x viminalis		04-106-026
S. lasiolepis x viminalis		04-106-073
S. nigra L.	AR 115	PN 733
S. nigra L.	Pryor 62-27	PN 734
S. pentandra L.	Dark French	PN 670
S. purpurea L.	Rubra	PN 221
S. purpurea L.	Links Dutch	PN 382
S. reinii Frach.& Sav. ex Seem.		PN 688
S. udensis		PN 283
S. X dasyclados	Korso	PN 669
S. X dichroa (aurita L.x purpurea L.)		PN 680
S. X forbyana (purpurea L.x viminalis L.)	Sessilifolia	PN 305
S. X reichardtii A. Kerner (caprea L.x cinerea L.)	Pussy Galore	PN 215
S. X reichardtii A. Kerner (caprea L.x cinerea L.)	Muscina	PN 714

Omarama Station. Fenced stream planted with oaks, alders and blossom species.

Figure 27 – Waioma Station: Part of the Wharekopae River headwaters fenced off at Pembroke Station and planted in native bee forage species in spring 2016. Twelve months later the pants are getting above the grasses, which have protected the soil and stream margin in the meantime.

5.2 Waioma Station, Gisborne

With the rapid expansion of the manuka honey industry it is becoming increasingly difficult for hill country farmers that rely on clover pasture to get beekeepers to put their hives on farm for the clover honey flow and resultant pollination. The owners of Waioma Station worked with local beekeeper Barry Foster and Trees for Bees to put together a planting programme to support bees on farm.

The purpose for establishing riparian planting at Pembroke (part of Waioma Station) was twofold. First, to help protect the headwaters of the Wharekopae River and second, to provide bee forage to support summer clover pollination and other pollinators (native and bumble bees). Plants were established on pasture at 3 x 3m spacing (1100 stems/ha) in spots sprayed before planting. At this spacing the grasses come away again, providing protection and screening for the riparian plants while letting them become established at a spacing that means they will grow into bushy and flower-laden plants (Figure 27). A list of the most successful species is given in Table 10.

Botanical Name	Common Name
Coprosma propinqua	Mingimingi
Cordyline australis	Cabbage tree
Corokia cotoneaster	Mountain Corokia
Dacrycarpus dacrydioides	Rimu
Dodonaea viscosa	Akeake
Hoheria sexstylosa	Lacebark
Knightia excelsa	Rewarewa
Kunzea ericoides	Kanuka
Leptospermum scoparium	Manuka
Olearia furfuracea	Akiraho
Phormium cookianum	Mountain flax
Phormium tenax	Swamp flax
Pittosporum eugenioides	Lemonwood
Pseudopanax arboreus	Five finger

Table 10 – Species list of the most successful bee forage plants established at Waioma Station.

5.3 Puketiti Station, King Country

The Mangaorongo River winds for about 4.5km through the lower reaches of Puketiti Station, located south-west towards the coast from Piopio. The sheep and beef breeding property has been going through a programme of fencing and creating laneways for stock movement, and as part of this has started to fence off the river for riparian protection. This work is now in its fourth year and is due to be completed in 2018, with support from Environment Waikato. Environment Waikato require a post and baton 8-wire fence, which is effective at keeping stock out of the planted area.

As part of the planning for riparian planting, bee forage species were included to support hives either side of the mānuka season and for clover pollination, and to provide support for native pollinators and bumble bees on the farm. Plants were established on pasture at 3 x 3m spacing (1100 stems/ha) in spots sprayed before planting. Grass was trampled around the plants 3-4 months after planting, with no further weed control required. Where there are potential pest issues (e.g. hares and goats), the grass is left longer before planting, so that the new plants aren't so obvious. Where goats are an ongoing issue, mānuka and kānuka have been used as they are less palatable. Vermin control on the farm is concentrated in the areas where there is new planting. At this spacing the grasses come away again, providing protection and screening for the riparian plants while letting them become established at a spacing that means they will grow into bushy and flower-laden plants. Plants are flowering after 2 years and are starting to fully occupy the site after 4 years (Figures 28 and 29). A list of the most successful species is given in Table 11.

Botanical Name	Common Name
Aristotelia serrata	Wineberry
Carpodetus serratus	Putaputaweta/marbleleaf
Coprosma robusta	Karamu
Cordyline australis	Cabbage tree
Dodonaea viscosa	Akeake
Fuschia exortica	Tree fuschia
Hebe parviflora	Hebe
Hebe stricta	Koromiko
Hoheria angustifolia	Narrow leaved Houhere
Hoheria sexstylosa	Houhere
Kunzea ericoides	Kanuka
Leptospermum scoparium	Manuka
Phormium cookianum	Mountain flax
Phormium tenax	Flax
Pittosporum colensoi	Rautawhiri
Pittosporum eugenoides	Lemonwood/Tarata
Pittosporum tenuifolium	Black matipo/kohuhu
Plagianthus regius	Ribbonwood
Pseudopanax laetus	Pseudopanax laetus
Sophora microphylla	Kowhai
Weinmannia racemosa	Kamahi

Table 11 – Species list of the most successful bee forage plants established at Puketiti Station.

Figure 28 – Puketiti Station: Part of the Mangaorongo River fenced off at Puketiti Station and planted in native bee forage species in spring 2017.

Figure 29 – Puketiti Station: Twelve months later the plants are getting above the grasses, which have protected the soil and stream margin in the meantime.

5.4 Callaghan Farm, Mid-Canterbury

The Callaghan's farm at Staveley in mid Canterbury is another property looking after home yard and over-wintering sites for summer honey and pollination work. It can be very cold and exposed, which limits the bee forage species suitable for planting, especially for autumn flowering (McPherson, 2018).

The farm has Flynn Stream flowing through the middle of it and borders Bowyer Stream. Bowyer Stream is fenced and they are gradually replacing senescent willows with Trees for Bees willows. Flynn Stream is being fenced off and planted in small sections over 4-5 years to keep the programme cost-effective. Planting of native and exotic riparian species has been undertaken since 2013, with ECan support for the native riparian planting. The challenge with native riparian planting in this area has been to design an indigenous species planting plan that included spring and autumn bee forage. This has been supplemented by exotic riparian planting with a mix of specimen trees, shrubs and groundcover to replace senescent willows and pines that have been removed.

Native species have been established at 3 x 3m spacing, and interplanted with tussock grasses as ground cover. Some exotic grasses have come away, but as with the other riparian plantings they provide protection and screening for the riparian plants while letting them become established at a spacing that means they will grow into bushy and flower-laden plants. The exotic specimens have been planted at 10m centres to allow them to grow to a good size unimpeded, and underplanted with smaller shrubs and ground cover.

Native plants started flowering after two years, the exotic shrubs at a similar time and the specimen trees after 3-4 years. After 4-5 years the planting sites are becoming fully occupied (Figures 30 and 31). A list of the most successful species is given in Tables 12 and 13.

Botanical Name	Common Name
Coprosma lucida	Karamu
Coprosma microcarpa	small leaf coprosma
Coprosma propinqua	mingimingi
Coprosma robusta	Karamu
Coprosma rubra	Red stemmed coprosma
Coprosma rugosa	Needle leaved mountain coprosma
Coprosma virescens	mingimingi
Cordyline australis	Cabbage tree
Corokia cotoneaster	Korokio
Discaria toumatou	Matagouri
Griselina littoralis	Broadleaf
Hebe salicifolia	Koromuka
Hoheria angustifolia	Narrow leaved Houhere
Hoheria lyallii	Mountain laceback
Myrsine divaricata	Weeping matipo
Nothofagus solandri	Black Beech
Olearia avicenniaefolia	Mountain akeake
Olearia nummulariifolia	subalpine Olearia
Olearia virgata lineata	Twiggy tree daisy
Phormium cookianum	Mountain flax
Phormium tenax	flax
Pittosporum eugenioides	Tatara/Lemonwood
Pittosporum tenuifolium	Kohuhu
Plagianthus regius	Ribbonwood
Pseudopanax crassifolius	Lancewood/horoeka
Pseudowintera colorata	Mountain horopito
Sophora microphylla	Kowhai

Table 12 – Species list of the most successful native riparian bee forage plants established at Callaghan Farm.

Figure 30 – Callaghan Farm: Native species riparian zone planting five years after establishment. The plants are becoming well established, fully occupying the site and flowering.

Figure 31 – Callaghan Farm: Exotic species riparian planting five years after establishment. The plants are becoming well established, starting to occupy the site and flowering.

Botanical Name	Common Name
Specimens	
Acer platanoides	Norway maple
Acer saccharum	Sugar maple
Alnus rubra	Red alder
Fraxinus ornus	Flowering (Manna) ash
Quercus canariensis	Mirbeck oak
Quercus cerris	Turkey oak
Quercus faginea	Portuguese oak
Quercus robur	English oak
Shrubs	
Crataegus chrysocarpa	Fireberry hawthorn
Crateagus jonesiae	Jones hawthorn
Luma apiculata	Chilean myrtle
Morus nigra	Black mulberry
Pseudocydonia sinensis	False quince
Ground cover	
Borago officianalis	Blue borage

Table 13 – Species list of the most successful exotic riparian bee forage plants established at Callaghan Farm.

Callaghan Farm. Native riparian planting showing stream crossing.

APPENDIX: THE WIDER CONTEXT FOR RIPARIAN PLANTATIONS

To understand how to proceed methodically in planning a bee forage plantation that will optimally benefit honey bees in general or an apiary site(s) on your property, it is helpful to have information about the biology and ecology of bee foraging systems. For example, your goals may be to service certain apiary sites in spring or autumn, or pollinate clover or other crops on your or nearby properties. Another goal may be for harvesting a valuable monofloral honey such as mānuka where abundance and purity of the honey are major issues (see discussion in McPherson and Newstrom-Lloyd 2018).

This appendix presents information on how to understand bee biology and ecology for targeted pollination services and for the general build-up and maintenance of bee colonies for targeted apiary sites. The planting designs for riparian areas combined with floral resources from pre-existing or planned bee plantations in adjacent areas can be strategically designed to maximise the abundance and quality of bee forage overall and ensure that any other competing flower patches do not distract the bees from your target flower patches for pollination services. These larger goals require taking a "big picture" approach to cover the entire foraging range for the bees from a given apiary site.

Challenges to honey bee colonies in context

Fast growing industries are accompanied by emerging challenges. The boom in the mānuka industry since the mid 2000's has seen New Zealand's hive numbers more than double, with exponential growth in hive numbers in the last five years (Newstrom-Lloyd 2015, 2016; Brown et al, 2018). This dramatic increase in hive numbers places pressure not only on the nectar flow during the honey season in summer, but also on pollen and nectar resources prior to and following summer.

The impact is not only on honey bees but also on all other bees including bumble bees and native bees as well as all other pollinating insects such as moths, flies, and beetles and in some cases also bird pollinators. The limits of the carrying capacity (the number of bees or pollinators that can be supported in a given area) are significantly influenced by the amount of the necessary year round floral resources to sustain the honey bees and all other pollinator populations that need nectar and pollen.

A domesticated honey bee colony is a complex population with a queen and different age class bees living in a hive and operating as a unit or 'superorganism'. The different age classes must be balanced correctly for the colony to survive. Each bee colony lives in one hive and many hives are aggregated into an apiary site managed by the beekeeper. The goal is to maintain healthy "age-class balanced colonies" and keep all the colonies within the apiary at equal strength to prevent the colonies from robbing honey from each other. Balanced colonies and balanced apiary sites promote cost effective beekeeping for pollination services and honey harvesting.

It is critical that the number of colonies (hives) per apiary does not exceed the carrying capacity of the floral resources in the foraging area. Hive numbers can exceed carrying capacity due to overcrowding too many apiaries in one foraging area and from overstocking an individual apiary with too many hives. Keeping the colony numbers in the bee foraging area at (or just under) the carrying capacity will ensure a maximum honey harvest and healthy thriving bee colonies. Too many bees will result in reduced honey yields because bees use up about one third to one half of the honey harvest to sustain the colony, a typical overstocking problem. In addition, too close proximity of apiaries or overloaded apiaries foster increased incidences and spread of bee pests and diseases. Overcrowding and overstocking puts bees at risk for starvation and malnutrition which leads to lower resistance to pests, diseases, and pesticides, just as it does for any livestock.

Lowering hive stocking rates and increasing bee forage planting will raise the level of natural floral resources to buffer seasonal fluctuations and severe weather events -- which will become more frequent through anthropogenic climate change. Many hives starve and suffer from elevated levels of pathogens in spring if they are under stress and living 'on the edge' in terms of available bee nutrition. It is recommended to build resilience into available bee forage by ensuring there is always a buffer of a diversity of natural floral resources available. Any selection of bee forage species should include some plants with long flowering periods such as tagasaste (tree lucerne, ***Chamaecytisus palmensis)*** and koromiko ***(Hebe*** (or ***Veronica) stricta),*** so that flowers will be available to bees in between successive bad weather events. Overlapping flowering times from a diversity of plant species also helps to ensure a continual supply of nectar and pollen.

While many beekeepers now provide supplements (e.g., protein patties), for extra bee food, a diversity and abundance of fresh natural pollen has been shown to be central to bee health, immune response and colony growth (Black, 2006; Brodschneider & Crailsheim, 2010; Di Pasquale et al., 2013; DeGrandi-Hoffman et al., 2015; Mao, et al. 2013). Supplements are excellent emergency rations for poor weather conditions that restrict bee flight for foraging trips but they are costly to supply for extended periods. A diet primarily based on supplementary feed does not measure up to fresh natural pollen, as it is impossible to precisely replicate the mix of nutrients and trace elements required by the bees at any one time, just as a farmer wouldn't feed livestock on silage, hay and supplements year-round. In addition, some supplement formulas have excessive amounts of certain nutrients that become toxic to bees when in excess. Too little is known about the nutritional requirements for honey bees to allow extended use of supplements at this stage (Doug Somerville, pers. com.).

For these reasons, to meet the demand from increased hive numbers and alleviate the overcrowding and overstocking issues, the apiculture industry has recognised that the installation of spring and autumn bee forage is required to bracket the honey harvest during the off-season. Provision of fresh natural pollen and nectar is one of the most compelling reasons to plant bee forage to help bees survive. This option promotes a long-term sustainable and profitable apiculture industry by promoting healthy strong bees.

A second challenge resulting from overcrowding and overstocking has been the conservation risk for the preservation of other pollinators that also rely on the same pollen and nectar resources in natural areas. Native insect pollinators, primarily bees, moths, butterflies and flies, derive sustenance from a range of plant species that are shared with honey bees in areas of high density apiaries. The competitive resource pressure on native insect flower visitors has been outlined by Newstrom-Lloyd (2013), Beard (2015) and the Department of Conservation (2015) but little data is yet available to document the extent of this issue. Nonetheless, to forestall or remedy such problems, installations of more off-season bee forage including riparian planting will help protect native pollinator ecosystems from overexploitation.

Bee-flower interactions

Natural bee forage consists primarily of pollen and nectar from flowers and sometimes from honeydew if available. A good supply of natural bee forage throughout the seasons provides the best nutrition for sustaining the number, strength and health of bee colonies. Superior pollination services and honey harvesting depend on a strong bee workforce to collect nectar or pollen in the crop. Honey bees require year-round food to build up colony strength to be ready for peak summer honey harvesting and pollination services. Crop pollination tends to be for relatively short periods especially for arable and horticultural crops but also pasture clover, so bees require off season food especially to survive through autumn and winter as well as build up in the spring.

Understanding bee—flower interactions plays a significant role in optimising the forage available for bees so that the colony can thrive. Important factors are (1) the colony's annual supply and demand for pollen and nectar; (2) the bee's foraging range in relation to the scale of the bee plantations; (3) the bee's floral preferences and risk of distraction away from the targeted goals of pollination or honey harvesting. The tools that we use in our demonstration farm bee plantations rely on the flowering calendar to calculate and engineer the annual bee forage budget.

Annual supply and demand of pollen and nectar

A honey bee colony passes through different phases of pollen and nectar demand throughout its annual cycle. The colony's size in each phase is shown in Figure 32 depicting the annual build-up and decline of a bee population in one hive in relation to typical bee activities in most of New Zealand (Matheson and Reid 2011). For each phase, the bee forage budget must supply pollen for protein to feed the brood, queen and emerging worker bees and nectar for carbohydrates to supply energy to all bees as well as to make wax and royal jelly. Water is also needed for making royal jelly and cooling the hive. Seeley (1995) estimates that for one bee colony (hive) the total annual bee forage budget is about 20 kg pollen, 120 kg nectar and 25 litres of water.

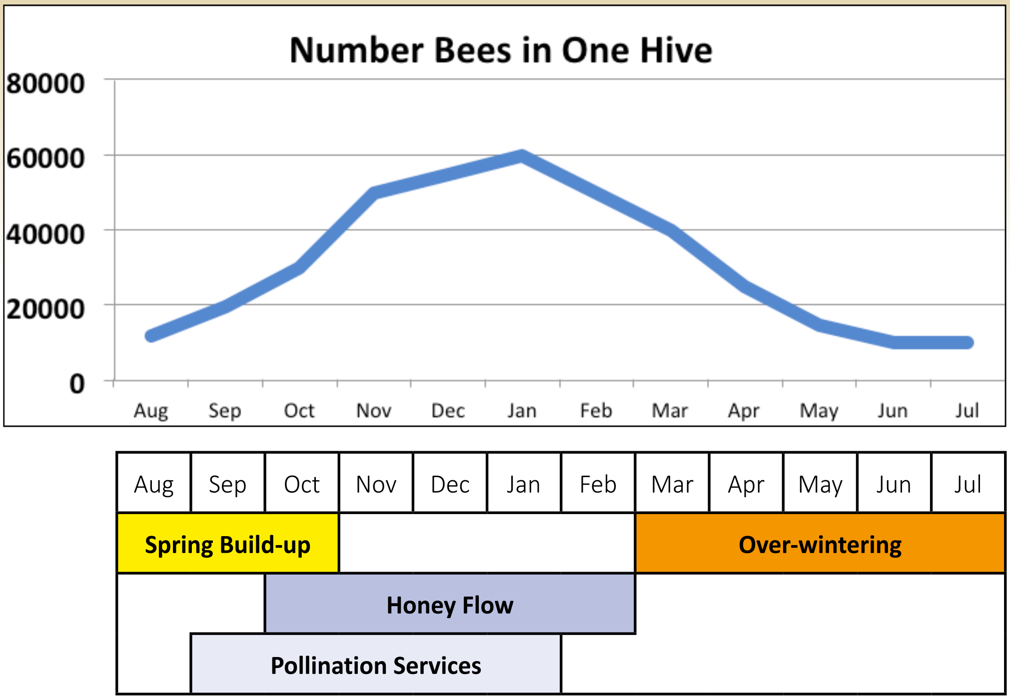
The first phase of the annual bee colony life cycle is in the **winter** season when the bees are normally resting especially in temperate climates with cold winters. In New Zealand, most honey bee colonies overwinter for one to three months from roughly late May to early August. As winter is approaching, the bee population starts to diminish until it reaches its lowest population size of about 10,000 bees per colony for the winter. In the coldest regions, the colony often has little to no brood (which presents an advantage for varroa control). Since New Zealand has mild winters in many regions it is possible on warm sunny days for bees to fly out of the hive to forage if there are available flowers close by. The queen will resume laying eggs at some point in the mid to late winter to start preparing for the next phase.

The second phase is in the early to mid-**spring** season which is by far the most critical because this is when the colony intensifies brood rearing to build-up the population size for the approaching summer activities. The queen increases brood production while worker bees collect massive amounts of pollen to feed the new brood and huge quantities of nectar to make foundation wax and royal jelly as well to fuel foraging flights. At this time, the beekeeper needs to gain an exponential growth rate for the bee colony to reach its peak population size of about 60,000 to 80,000 bees in time for honey production and pollination services. This requires a significant supply of nutritious pollen to raise new brood rapidly. This population growth must be sustained through spring because any interruption in pollen supply results in bees cannibalising the youngest larvae to feed protein to the older brood. This is the worst case apart from colony death by starvation, as any cannibalising has a compounding effect on colony population growth and can cause population crashes. This becomes a timing issue as any break in colony build-up in spring cannot be made up later.

If the colony does not reach peak size on time then a maximum honey harvest will not be attained because only a small number of mature bee foragers are available to collect nectar. In this case the colony is not able to store surplus nectar because all resources are still supplying the population build-up. In other words, any nectar collected in this situation will go to sustaining the bees during colony build-up, not to storing surplus nectar for honey. For beekeepers providing pollination services, if the colony does not grow properly during this period then the hives might not meet specified pollination contract standards. The colonies will be too small and the bees will not be strong enough to provide good pollination services.

The third phase is in the **summer** season when the pollen demand continues because the queen is still producing brood to sustain the colony. There needs to be enough adult bees available to focus on collecting surplus nectar for honey stores to provide for winter as well enough nurse bees to bring up

Figure 32. Bee colony population size and annual cycle showing pollen and nectar demand and typical activities for each season.



the next generation. It is this surplus honey that provides the harvest for beekeepers. Honey is important because it subsidises beekeeper's income from pollination services. Summer bees live for only six to nine weeks and so the turn-over of new emerging brood still requires quantities of pollen supply during summer. From late spring through summer, the surplus nectar flow starts for many honey species, including mānuka, tawari ***(Ixerba brexioides),*** rewarewa ***(Knightia excelsa),*** kamahi ***(Weinmania racemosa)*** and clover ***(Trifolium repens).***

The fourth and final phase is in the **autumn** season when bees are preparing for winter. This is the second most critical phase because the new brood raised at this time become "winter bees". In contrast to summer bees (living for 6 to 9 weeks only), winter bees must survive for two to three months depending on the duration and severity of the winter. Winter bees spend all or most of their time in the hive keeping warm by clustering together near the honey and pollen stores. To survive this long, the winter bees must be robust with high levels of protein and fat stored in their bodies – hence the need for good pollen and nectar sources in autumn. Additionally, the colony must replace the stored honey that was removed during the honey harvest by the beekeeper if insufficient honey has been left in the hive. An alternative is for the beekeeper to leave a supply of sugar syrup but this is not ideal compared to honey stores and incurs a labour and materials cost. If a good pollen and nectar supply in autumn is not available to raise strong winter bees, then the colony may become too weak to survive winter and succumb to pests and pathogens as well as starvation. Even if a weak colony does survive it may still be too small to build-up rapidly enough in the spring in time for honey harvest. For this reason, autumn pollen and nectar supply are as crucial as the spring supply because it ultimately contributes to maximum honey harvesting and pollination capacity of the colonies in the summer.

Foraging range and scale of combined bee plantations

Scale is important in calculating annual bee forage budgets for some of the overall goals discussed above. An understanding of how the riparian plantation fits into the overall bee foraging range and interacts with surrounding vegetation, floral resources, topography and apiary sites is important for maximizing the benefits from bee forage in riparian planting. Bee flight is unrestricted by fences so the foraging range can be very large depending on the type and extent of the flower patches within flying distance. This means that bees are capable of flying to any nearby competing pollen or nectar source and will do so if a more abundant and superior source is available within foraging range. This also means that the riparian planting can be designed to suit specific purposes and timing of flowering relative to these other sources. From the apiary density perspective, it means that all floral resources within the foraging range, including the riparian planting, will be available to all other neighbouring bee colonies within the same foraging range (Newstrom-Lloyd 2016).

Bees will fly various distances depending on the location of the most profitable flower patches in the vicinity of the apiary. The longest distance recorded for honey bee flights have been 13.5 km but we do not know what the maximum distance could be (Beekman and Ratnieks 2000). Honey bees are known to fly an average of 5.5 km and up to 10 km away for good nectar sources, for example to collect resources from heather ***(Calluna vulgaris)*** the UK. Such long distances are not common, however, because most records show bees tend to forage close to the apiary: for example, more than 90 % of the foraging trips typically occur within four km of a hive (Beekman et al. 2004). Beekeepers in New Zealand have considered that a separation distance for apiaries should be two to three km and this has always been observed by longstanding incumbent beekeepers in the past but many new entrants to the apiculture industry do not comply to this for various reasons, hence overcrowding.

The circular area around an apiary with a one km radius covers an area of 314 hectares while a 2 km radius covers 1256 ha and a 3 km radius covers 2827 hectares. These areas are the potential extent of the foraging ranges to consider when assessing the opportunities for competing flowers that may distract the bees from your goals such as clover or crop pollination on your property. Competing apiaries may be placed too close to the spring and autumn bee forage that are needed by any apiary site on your property.

Bees cannot be prevented from foraging to any area by placing obstacles in their path. Bees are conservative and will fly as high as they need to, but not much higher than the height of any obstacle in its path, yet they are capable of flying as high as at least 30 m and probably more (British Beekeeping Association 2017). This means that a high shelter belt or variation in topography will not prevent bees from going over to the next paddock or farm. Bees will follow a flight path to expend the least energy for the most gain and have been observed following planted riparian corridors that provide shelter (Barry Foster, pers comm). If these riparian corridors are planted with bee forage species, then there is an added benefit for bees.

The foraging range that bees actually do use affects the quantity and quality of the pollen and nectar stored and the honey yield. When bees have to fly further than optimal, they require more nectar to fuel their long return flights and this leads to slower build-up of the colony and also lower honey yields (Newstrom-Lloyd 2015, 2016). Any overcrowded or overstocked apiaries closer than the recommended separation distance forces all bees to forage further afield with consequent reduction in honey yields and purity for everyone with apiaries in the area. A greater number of colonies within a foraging area uses up more honey because more bees require more maintenance nectar to sustain the colony. When carrying capacity is exceeded, bees are forced onto alternative less desirable nectar sources resulting in diluted or contaminated monofloral honey.

Depending on your goals some of the above factors may need to be considered. It is desirable to summarise the flowering calendar and annual bee forage budget over the whole farm or the extent of the foraging range if that is possible. This will help to understand what role the riparian planting has in the wider context of the bee foraging range.

TW Wines: Duck pond planted with oaks and spring blossom crab apple species.

GLOSSARY OF TERMS USED FOR PLANNING A BEE FORAGE PLANTATION.

1. Flowering calendar	The flowering calendar is a list of plant species or cultivars and the months in which they typically start and end flowering. It is usually represented in a table as a matrix of plant names and flowering months with the number one in each cell to represent that flowering is present or absent in the given month. It is the basis for the species diversity chart and the bee forage profile.
2. Species diversity chart	The species diversity chart is the list of plants selected from the flowering calendar for a given plantation site. It is represented in graphical form as the total number of species flowering in each month (column totals as a bar chart). This chart is created to ensure, as far as possible, that there is sufficient flowering diversity in each month of the year. The species diversity chart can be used for pre-existing plant species, proposed plant species to be planted or a combination of the two. It can be created for single or multiple sites (e.g. riparian, shelterbelt, existing native forest) and/or seasons (e.g. spring build-up, pollen sources during mānuka flowering, summer/autumn flowering).
3. Bee forage profile	The bee forage profile is based on the species diversity chart except that we insert the number of plants for each species. This is achieved by either directly replacing the number 1 in each cell with the number of plants for that species, or by multiplying the species diversity chart cell entries by the number of plants for each species to create a second chart. As a planning tool for planting, the number of plants for each species is adjusted until the desired bee forage profile is achieved. For example, it is used to ensure that the correct timing is optimised to fill gaps or to increase bee forage during spring build up or to ensure sufficient bee forage immediately following honey/pollination work to assist hive recovery. It is also used to ensure that bee forage flowering times do not compete with target honey or pollination services by distracting the bees.
4. Annual bee forage budget	The annual bee forage budget is the combination of a number of bee forage profiles over a wide area such as a 3 to 5 km foraging area for a particular apiary site or a number of apiaries on a property. The area covered will vary depending on logistics but the goals are to determine that there is sufficient diversity and quantity of bee forage within the forage range to sustain the apiary. The annual bee forage can be calculated based on how the apiary site is used, whether it is residential all year round or is seasonal for pollination and/or honey, spring build-up, over-wintering, or permanent (e.g. Queen raising yards).

REFERENCES

Apiculture New Zealand (2017). Apiculture New Zealand Beekeeper Code of Conduct. Retrieved from http://www.apinz.org.nz

Beard, C. (2015). Honey (Apis Mellifera) on Public Conservation Lands: A Risk Analysis. Department of Conservation Technical Report. Wellington: New Zealand Department of Conservation.

Beekman M, Ratnieks FLW. (2000). Long-range foraging by the honey-bee, Apis mellifera L. Functional Ecology 14:490-496.

Beekman M, Sumpter, DJT, Seraphides N, Ratnieks FLW. 2004. Comparing foraging behaviour of small and large honey-bee colonies by decoding waggle dances made by foragers. Functional Ecology 18:829-835.

Black, J. (2006). Honeybee nutrition: Review of research and practices. Rural Industries Research and Development Corporation. RIRDC Publication No 06/052. RIRDC Project No JLB-2A.

British Beekeeping Association (2017) General Information. Biology – interesting facts. https://www.bbka.org.uk/learn/general_information/biology__interesting_facts

Brodschneider, R., & Crailsheim, K. (2010). Nutrition and health in honey bees. Apidologie, 41(3), 278-294.

Brown, P., Newstrom-Lloyd, L. E., Foster, B. J., Badger, P. H., & McLean, J. A. (2018): Winter 2016 honey bee colony losses in New Zealand, Journal of Apicultural Research, DOI: 10.1080/00218839.2018.1430980

DeGrandi-Hoffman, G., Chen, Y., Rivera, R., Carroll, M., Chambers, M., Hidalgo, G., & De Jong, E. W. (2016). Honey bee colonies provided with natural forage have lower pathogen loads and higher overwinter survival than those fed protein supplements. Apidologie, 47(2), 186-196.

Department of Conservation (2015). Beekeeping National Guidelines (Interim 2015), Version 1. Retrieved from http://www.doc.govt.nz

Di Pasquale, G., Salignon, M., Le Conte, Y., Belzunces, L. P., Decourtye, A., Kretzschmar, A., ... & Alaux, C. (2013). Influence of pollen nutrition on honey bee health: do pollen quality and diversity matter?. PloS one, 8(8), e72016.

Dornhaus A, Klugl F, Oechslein C, Puppe F, Chittka L. 2006. Benefits of recruitment in honey bees: effects of ecology and colony size in an individual-based model. Behavioral Ecology. Doi:10.1093/beheco/arj36.

Environment Canterbury (2011). Riparian Zones. A guide to the protection of Canterbury's rivers, streams and wetlands.

Foster, B. J. 2014. Designing the ideal apiary site. Kauri Park Nursery. http://www.kauriparknurseries.co.nz/designing-ideal-apiary-site/

Mao, W., Schuler, M.A., Berenbaum, M.R. 2013. Honey constituents up-regulate detoxification and immunity genes in the western honey bee *Apis mellifera.* PNAS Early Edition. www.pnas.org/cgi/doi/10.1073/pnas.1303884110

Matheson, A. (1984). Practical Beekeeping in New Zealand. Wellington, New Zealand: The Government Printing Office.

Matheson A, Reid M. 2011. Practical Beekeeping in New Zealand. Exile Publishing Limited, Auckland, New

Ministry for Primary Industries (2017a). Apiculture: 2016 Apiculture Monitoring Programme. Retrieved from http://www.mpi.govt.nz/

Ministry for Primary Industries (2017b). Farm management for healthy waterways. Retrieved from https://www.mpi.govt.nz/growing-and-harvesting/land-care-and-farm-management/farm-management-for-healthy-waterways/

McPherson, A. and Newstrom-Lloyd L.E. (2017) Guide to Planting for Bees. PDF available at http://www.treesforbeesnz.org/publications/

McPherson, A. (2018). Looking after your own patch. New Zealand Beekeeper, June, 24-29.

McPherson, A. and Newstrom-Lloyd L.E. (2018) Handbook for Manuka Plantations and Farms: Profitable and sustainable manuka honey harvesting. PDF available at http://www.treesforbeesnz.org/information

Mowbray, S. C. (2002). Eradication of introduced Australian marsupials (brushtail possum and brushtailed rock wallaby) from Rangitoto and Motutapu Islands, New Zealand.

Newstrom-Lloyd, L. E. (2013). Pollination in New Zealand. Ecosystem Services in New Zealand: Conditions and Trends. Landcare Research, Lincoln, New Zealand, 408.

Newstrom-Lloyd, L. E. (2015). Managing mānuka for carrying capacity and competition. The New Zealand Beekeeper Journal 23(11): 18–19.

Newstrom-Lloyd, L. E., McIvor, I., Jones, T., Gabarret, M., Polturat, B. (2015). Winning with Willows. Extending the supply of nutritious pollen for bees in spring. PDF available at http://www.treesforbeesnz.org/publications/

Newstrom-Lloyd, L. E. (2016). Bees without Borders: What is the limit? The New Zealand BeeKeeper Journal 24(9): 22 –27.

Newstrom-Lloyd L.E., Raine I, Li X. 2017. The Power of Pollen Profiles. PDF available at http://www.treesforbeesnz.org/publications/

Palmer-Jones, T., & Line, L. J. S. (1962). Poisoning of honey bees by nectar from the karaka tree (Corynocarpus laevigata JR et G. Forst.). New Zealand Journal of Agricultural Research, 5(5-6), 433-436.

Seeley, T. D. (1995). The wisdom of the hive: The social physiology of honey bee colonies. Cambridge, MA: Harvard University Press.

Sopow, S. (2018). Management of Giant Willow Aphid. Scion Annual Newsletter June 2018.

Tautz, J. (2008) The Buzz About bees: Biology of a Superorganism. Springer-Verlag Berlin and Heidelberg GmbH & Co. K.

Turcatto, A.P., Lourenco, A.P., De Jong, D. 2018. Propolis consumption ramps up the immune response in honey bees infected with bacteria. Apidologie 49: 287-296.

Project Crimson Trust (2018). Regional guides for panting natives. Retrieved from https://www.treesthatcount.co.nz/resources/regional-guides-for-planting-natives/

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Ministry for Primary Industries
Sustainable Farming Fund Project 404868

Strategic Planting for Pollination and Honey 2016 – 2019

Ministry for Primary Industries
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ACKNOWLEDGEMENTS

Our thanks to our sponsors for their continuing support. Special thanks to the following people who provided valuable feedback in completing this handbook: James Callaghan, Ben Douglas and Warwick Hesketh (Hawke's Bay Regional Council), Barry Foster (Tawari Honey), Matt Harcombe (Silver Fern Farms), Anna Roberts (Waioma Station), and Jeremy Williams (Ingleby NZ LP).

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