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AN ASSESSMENT OF THE CONTRIBUTION OF HONEY BEES (*APIS MELLIFERA*) TO WEED REPRODUCTION IN NEW ZEALAND PROTECTED NATURAL AREAS

Summary: Recent concern that honey bees may threaten natural areas by increasing weed abundances through increased pollination was investigated by reviewing the literature to determine which weed taxa surveyed from New Zealand Protected Natural Areas (PNAs) are visited by honey bees. The contribution made by honey bees to weed reproduction was assessed by checking reproductive strategies and pollination mechanisms of a subset of problem weeds. A substantial proportion of surveyed weeds in PNAs are probably visited by honey bees (43%) including half of the problem weeds. However, reproduction of the majority of problem weeds is characterised by plastic reproductive mechanisms and/or simple pollination mechanisms where honey bee influence is low or unimportant. Although honey bees may be important pollinators of some weeds, they probably do not contribute substantially to weed problems.

Keywords: *Apis mellifera*; introduced plants; weeds; protected natural areas; pollination; reproduction.

Introduction

Since its introduction in 1839, the honey bee (*Apis mellifera* L.) has become a visitor to much of the flora throughout New Zealand (Walsh, 1967; Matheson, 1984; Butz Huryn, 1995). The environmental role of honey bees has traditionally been seen as beneficial or positive by increasing pollination of flora while simply extracting the 'surplus' abundances of pollen and nectar. This long-held view has recently been challenged, however, by some scientists and conservationists. Although supporting evidence is largely lacking, questions regarding the impact of introductions of honey bees range from considerations of potential negative effects such as damage to native plant populations through inferior or inefficient pollination compared to native pollinators, increased hybridisation of native flora, and physical damage of plants, to competitive interactions with native fauna for floral resources (e.g., Robertson *et al*., 1989). The possibility that honey bees contribute to higher introduced weed abundances through increased pollination has also been considered a potential threat to New Zealand's natural areas.

Cultivated, introduced crop plants such as clovers provide the main marketable honey crops for many beekeepers in New Zealand (Donovan, 1980). However, some introduced weeds are also important sources of both nectar and pollen for honey bees and the potential exists for beekeeping to exacerbate weed problems. Only with adequate knowledge of the reproductive biology of individual weed species is it possible to determine the extent pollination plays in the spread of weeds. As a rule, weedy species tend to be quite plastic and this plasticity may include breeding systems often favoring self-pollination, unspecialised pollination, high germination potential, and many refinements for seed dispersal (Hill, 1977; van der Pijl, 1982). As invasive exotics, release from natural competitors and antagonists may confer weed status on a plant non-weedy in its native environment. If escape from natural regulators is a primary factor influencing the weediness of a plant, and pollination is required, a weed could potentially be contained by the lack of a pollinator. If honey bees are suitable or important pollinators, regulation of their numbers might help limit seed production. If however, weediness is a function of other factors such as a high degree of vegetative reproduction, self-pollination, or unspecialized pollination which could equally be effected by other native and introduced pollinating species, regulation of honey bee numbers would not help control weed abundance.

This paper examines the extent to which honey bees may contribute to the spread of weeds in Protected Natural Areas (PNAs) by: 1) reviewing the literature to estimate use of surveyed weed taxa found in New Zealand PNAs (Williams and Timmins, 1990) by honey bees; and 2) assessing the reproductive strategies of problem weeds (cf.

Williams and Timmins, 1990) potentially used by honey bees for the relative contribution of honey bees to pollination and reproduction.

Methods

Weeds visited by honey bees in New Zealand PNAs

Introduced weeds reported from New Zealand PNAs during a survey conducted for the Department of Conservation (Williams and Timmins, 1990) were examined for inclusion in a list of weeds used by honey bees (Table 1). Evidence of honey bee visitation of weeds was obtained primarily from references listed in the Bibliography of New Zealand Apiculture, 1842-1986 (Reid, Matheson and Walton, 1988). Additional species found in important honey-producing genera (Crane, 1976) were included in the list and species of weeds recognised as important for honey or honeydew production in some area of the world according to Crane (1976) were noted. It should be recognised that a far greater number of exotic plants may be found in New Zealand PNAs including a fair percentage of all introduced flora, although most are not serious weeds, (Timmins, S.M. *pers. comm.*). Therefore, we assume the list by Williams and Timmins (1990) reflects notable weeds.

Information in Table 1 was compiled according to the following conventions. Scientific names, habit, and bloom periods follow Healy and Edgar (1980) and Webb, Sykes, and Garnock-Jones (1988). Common names follow Williams and Timmins (1990) and weed names taken from the references (Appendix 1) were standardised using Healy (1984). The plant resource (pollen or nectar) used by honey bees, as cited by Matheson (1982) and Walsh (1967), is given where available. Plants providing honey bee colonies with known surpluses of honey (quanitities of stored honey above current colony maintanence requirements) were noted by Matheson (1982) and Walsh (1967). Other species not cited in Matheson (1982) and Walsh (1967) were often listed as valuable honey or 'bee' plants and were given as nectar resources by the other references unless specifically noted as pollen sources. Nectar was assumed as the resource for plants recorded by Peterson (1934, 1935, 1936) because of his title "The honey plants of New Zealand" although nectar was often not specified. Day *et al.* (1990) listed only pollen sources. References were subdivided into major and minor references according to Butz Huryn (1995). Pollens found from analysis of honey were noted separately. Most pollens in honey were identified only to genus.

Problem Weeds

Of the 158 weed taxa reported from the survey of PNAs, 65 were considered 'problem weeds' because 'they permanently alter the structure, successional processes, and organisms present in native communities' (Williams and Timmins, 1990). The problem weeds in Table 1 were further assessed for the relative importance of reproductive strategies and pollinators. Because pollination is effected by abiotic and biotic pollen vectors, problem weeds used by honey bees were divided into two groups: 1) those pollinated abiotically (primarily anemophilous or wind-pollinated plants); and 2) those potentially pollinated by biotic vectors including primarily entomophilous (insect-pollinated) plants.

The weeds in Table 1 are probably *visited* by honey bees for either pollen or nectar. Actual *pollination* effecting fertilisation cannot be inferred from visitation records. However, visitation records may show trends among plants and usual pollinators. Flowers are often broadly classed according to pollination syndrome which is usually determined by their odour, colour and morphology, and the interaction of these characteristics with major visitors and pollinators (Knuth, 1906; Baker and Hurd, 1968; Faegri and van der Pijl, 1979). Therefore, the problem weeds potentially pollinated by honey bees and other biotic pollen vectors were checked against visitor lists compiled mainly by Knuth (1906, 1908, 1909) and Proctor and Yeo (1973) (Table 2) to roughly

Table 1: *(table opposite) Checklist of weeds probably used by honey bees in New Zealand Protected Natural Areas. Checklist is based on a survey of weeds reported in PNAs by Williams and Timmins (1990). Numbered references citing honey bee use of flora are given in Appendix 1.*
• = problem weed found in N.Z. PNAs (after Williams and Timmins, 1990); + = important for honey or honeydew production in some area of the world (after Crane, 1976); G = referenced to genus. ***Resource*** *- type of bee food (pollen = P, or nectar = N) cited in honey bee forage reference 1 and 2: * = known surplus honey stores produced by colonies using this plant in references 1 and 2. For reference 1, the following system is used (after Matheson, 1982): NP = used more as a source of nectar than of pollen; PN = used more as a source of pollen than of nectar; P = pollen source only; N = nectar source only; N:P = equally valuable for pollen and nectar; HD = source of honey dew.* ***Reference*** *(after Butz Huryn, 1995): Major- describe bee forage sources throughout N.Z. PIH - pollens in honey; is denoted by "G" in column if only identified to genus (e.g., 5G). Minor - describe regional and specific nectar and pollen sources.*

Table 1: *(caption opposite)*

	Common name	Habit	Flowering period	Resource	Major reference	PIH	Minor reference
ACERACEAE							
• *Acer pseudoplatanus* +	sycamore	tree	Oct-Nov	NP(1)	1		12a,17,19,24,37
APIACEAE							
Conium maculatum	hemlock	herb	Sep-Jan	N	2		
Foeniculum vulgare +	fennel	herb	Nov-May	NP(1);N	1,2,3b(x)		
ARACEAE							
Zantedeschia aethiopica	arum lily	herb		P(2)	2		
ARALIACEAE							
• *Hedera helix* +	ivy	climber	Mar-May	N			
ASTERACEAE						5	
Carduus nutans +G	nodding thistle	herb	Jul-Jun	NP*(1)	1		10, 36
• *Hieracium pilosella*	mouse ear hawkweed	herb	Oct-May	N,P(2)	2		13
• *Hieracium praealtum*	king devil hawkweed	herb	Sep-Apr				
Hieracium spp.	hawkweed	herb	Sep-May	N,P(2)	2		18
Hypochoeris radicata	catsear	herb	Nov-Mar	N:P(1);N,P*(2)	1,2,3a(iv),3b(i),4		6,13,15,16,18,23,27,35
Leontodon taraxacoides	hawkbit	herb	Sep-Apr	N,P(2)	2,4		6,15,27
• *Leucanthemum vulgare*	oxeye daisy	herb	Aug-May	N	3b(i)		
Senecio angulatus +G	Cape ivy	herb	Mar-Aug	N			
Senecio jacobaea +	ragwort	herb	Nov-Apr	N(2);N,P(3)	2,3b(ii)		15,23,27,31
• *Senecio mikanioides* +G	German ivy	herb	Mar-Oct	N			
BERBERIDACEAE							
• *Berberis darwinii* +G	Darwin's barberry	shrub	Jan-Dec			5G	
• *Berberis glaucocarpa* +G	barberry	shrub	Sep-Nov	NP*(1);N,P*(2)	1,2,4		16,23,27,39
BORAGINACEAE							
Echium vulgare +	viper's bugloss	herb	Oct-May	NP*(1);N	1,2,3b(xviii),4	5G	12b,15,27
CAPRIFOLIACEAE							
• *Leycesteria formosa*	Himalayan honeysuckle	shrub	Dec-May	N	2		
CARYOPHYLLACEAE						5	
Cerastium fontanum ssp. *triviale*	mouse-ear chickweed	herb	Aug-Jun	N	2,3b(xii)		
ERICACEAE						5	
• *Calluna vulgaris* +	heather (ling heather)	shrub	Dec-Mar	N:P*(1)	1	5G	8,10,11b,36
• *Erica lusitanica* +G	Spanish heath	shrub	Mar-Sep	NP(1);N	1,2		12b
FABACEAE							
Chamaecytisus palmensis	tree lucerne	shrub	Apr-Oct	NP(1);N,P(2)	1,2,3a(i,iv),3b(vi)		17,19,20,21,23,24,25,40
• *Cytisus scoparius*	broom	shrub	Sep-Apr	P(1);P(2)	1,2,3b(vi)		13, 21, 26, 30, 34
• *Lotus pedunculatus*	lotus	herb	Nov-Jan	NP*(1);N,P(2)	1,2,3a(vii),3b(v),4	5G	6, 16, 23, 26, 27, 32a
• *Lupinus arboreus*	tree lupin	shrub	Oct-May	N,P(2)	2	5G	6
Paraserianthes lophantha	brush wattle	tree	May-Aug	NP(1);N*(2)	1,2		
Psoralea pinnata +	dally pine	shrub	Nov-Jan	N	2		
• *Racosperma dealbatum* +G	silver wattle	tree	Jul-Sep	P(2)	2,3a(iv),3b(vi)		37
Racosperma decurrens +G	green wattle	tree	Jul-Sep	P(1);P(2)	1,2,3a(iv),3b(vi)		19,37
Racosperma longifolium +G	golden wattle	tree	Jul-Aug	N,P(2)	2		
Racosperma mearnsii +G	black wattle	tree	Sep-Nov	P			24
Racosperma verticillatum +G	prickly wattle	tree	Sep-Nov	P(2)	2		
• *Robinia pseudacacia* +	robinia	tree	Nov-Jan	N:P(1);N,P*(2)	1,2,3b(vi)		20,24,37
Trifolium spp. +	clover	herb	various	NP*(1);N,P(2)	1,2,3a,3b(iii,iv,v),4	5G	6,9,10,11b,13,14,18,19,21,22, 23,27,28,29,31,32ab,35,36,39,41
• *Ulex europaeus*	gorse	shrub	Jan-Dec	P(1);N,P(2)	1,2,3a(iv),3b(vi)	5G	11b,13,14,18,21,26,27,29,30,33,34,39
FAGACEAE							
Quercus robur +G	oak	tree	Sep-Oct	HD			
LAMIACEAE						5	
Thymus vulgaris +	wild thyme	shrub	Sep-Dec	NP*(1);N*(2)	1,2,3b(iii)	5	7,11a,12b
MELIANTHACEAE							
Melianthus major	Cape honey flower	shrub	Jul-Apr	N	3b(ix)*		
MYRTACEAE							
Eucalytus globulus	blue gum	tree	Aug-Nov	N	3b(vi)		20,27,37
OLEACEAE							
• *Ligustrum lucidum*	tree privet	tree	Nov-Mar			5G	
Ligustrum ovalifolium	privet	shrub	Nov-Apr				
• *Ligustrum sinense*	Chinese privet	tree	Jul-Mar	NP(1);N,P*(2)	1,2,3b(xviii)		
Ligustrum vulgare	common privet	shrub	Nov-Jan	NP(1);N	1,2		
PHYTOLACCACEAE							
Phytolacca octandra	inkweed	shrub	Nov-Aug	N	2		
PINACEAE							
• *Larix decidua*	European larch	tree		P			29
• *Pinus contorta*	lodgepole pine	tree					
• *Pinus nigra* +	Corsican pine	tree		HD			
• *Pinus pinaster*	maritime pine	tree					
• *Pinus radiata*	radiata pine	tree		P(during dearth)	2		
Pinus spp. +G	pine	tree		HD		5G	6,11b,13,29
POLYGONACEAE							
Muehlenbeckia australis (native)	large-leaved pohuehue	liane	Nov-Dec	N,P(2)	2	5G	
Polygonum spp. +G	willow weed	herb	Oct-Mar	N	2,3b(xi,xviii)		
PROTEACEAE							
• *Hakea gibbosa*	downy hakea	shrub	Jun-Aug	N	3b(ix)	5G	
• *Hakea salicifolia*	willow-leaved hakea	shrub	Aug-Nov				
• *Hakea sericea*	prickly hakea	shrub	Jun-Nov	N:P(1);N,P(2)	2		
RHAMNACEAE							
• *Rhamnus alaternus* +	evergreen buckthorn	shrub	May-Nov	N			
ROSACEAE						5	
Cotoneaster spp.	cotoneaster	shrub	Sep-Jan		3b(ix)		
• *Crataegus monogyna* +	hawthorn	shrub	Oct-Nov	N:P*(1);N,P(2)	1,2,3b(ix)		12a, 41
Prunus avium +G	wild cherry	tree	Sep-Nov	N	1		
Prunus laurocerasus +G	cherry laurel	tree	Aug-Sep	N*(2)	1,2		
• *Rosa rubiginosa*	sweet brier	shrub	Nov-Jan	N,P(2)	2,3b(ix)		
• *Rubus fruticosus* agg. +	blackberry	shrub	Nov-Apr	NP*(1);N,P*(2)	1,2,3b(viii),4	5G	11b,13,16,23,26,27,32a,34,39
SALICACEAE							
• *Salix cinerea*	grey willow	shrub	Sep-Oct				
• *Salix fragilis*	crack willow	tree	Sep-Oct	N:P(1);N,P*(2)	1,2,4		12a, 14, 16, 20
Salix spp. +G	willow	tree	Jun-Sep	N,P*(1);N	1,2,4	5G	9,10,11b,12a,13,14,15,16,18,19,20, 21,23,24,25,27,29,30,32a,37,38,41
SCROPHULARIACEAE							
Digitalis purpurea +	foxglove	herb	Oct-Jan	P(2)	2,3b(xi)		29
SOLANACEAE							
Lycium ferocissimum	boxthorn	shrub	Jul-Mar	NP*(1);N,P*(2)	1,2,4		23

determine main or major pollination agents in their native environments. The visitor lists of both Knuth and Proctor and Yeo are for weed species of European origin which comprise the majority of problem weeds potentially used by honey bees in New Zealand (58%). The remaining weeds originate from the Americas (*Berberis darwinii*, *Lupinus arboreus*, *Robinia pseudacacia*), Australia (*Hakea*, *Racosperma dealbatum*), China (*Ligustrum*), the Himalaya (*Berberis glaucocarpa*, *Leycesteria formosa*), and South Africa (*Senecio mikanioides*) (Webb *et al*., 1988). Visitor records for these groups are sparse but were noted where possible.

Importance of honey bees in problem weed reproduction

Entomophilous problem weeds potentially used by honey bees were then checked for the potential of the weed for self pollination or apomixis; its vegetative potential; the availability of floral resources to potential pollinators; and the diversity of visitors to the plant (Table 3). From these factors, the relative importance of the honey bee in pollination and/or reproduction of the weed was gauged using the following criteria:

1) If plants were only abiotically pollinated, solely self-pollinated, obligate apomicts, or reproduced by vegetative propagation alone, the influence of honey bees was considered to be 'none'.
2) Plants with easily accessible floral rewards and very diverse visitors (including probable pollinators from at least two orders) or probable major pollinators other than bees, were given a 'low' level of influence on reproduction by honey bees.
3) A 'medium' level of influence was assumed for plants that had floral resources which were not fully accessible for many short-tongued visitors, but where nontheless flowers were known to be visited and probably pollinated by diverse visitors and/or were known to have alternate mechanisms for reproduction other than only sexual reproduction using biotic pollen vectors.
4) A 'high' level of influence was given to plants known to use honey bees as main pollinators.

Results

Weeds visited by honey bees in New Zealand PNAs

Although not exhaustive, the 1990 DOC survey noted 158 weed taxa in PNAs (Williams and Timmins, 1990). Of these, 54 (34.2%) are documented as being used by honey bees in New Zealand. A further nine species were added to this list because they belong to the same genus as other cited weed species and could potentially be honey bee forage species. Two additional species (*Hedera helix* and *Rhamnus alaternus*) were included because

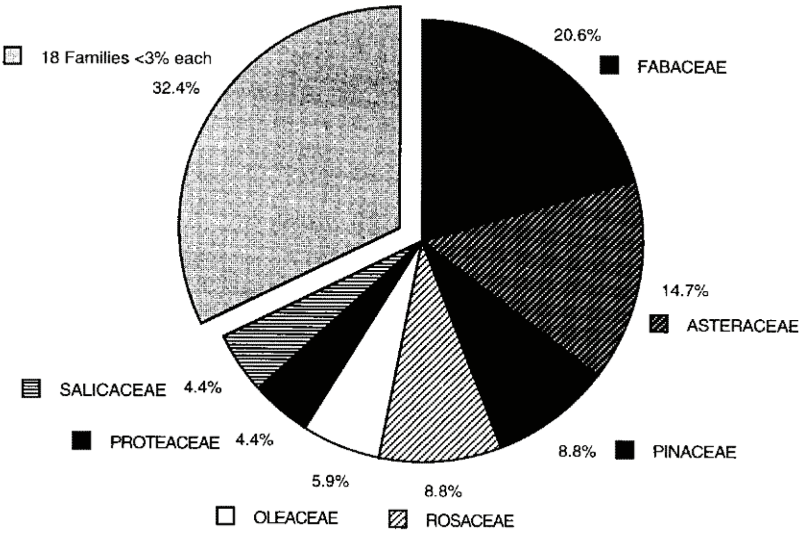

Figure 1: *Proportion of weed taxa in New Zealand Protected Natural Areas used by honey bees, according to family. Based on the survey list of Williams and Timmins (1990).*

they are well known as important honey producing species elsewhere and three species (*Senecio angulatus*, *S. mikanioides*, and *Quercus robur*) were included because they belong to well known nectar producing genera (Crane, 1976). A total of 68 groups of weeds (43% of the total weed taxa surveyed in Williams and Timmins, 1990) are potentially used by honey bees in New Zealand PNAs (Table 1).

The weed taxa used by honey bees in Table 1 are represented within 47 genera in 25 families. The Fabaceae (21%) and Asteraceae (15%) contain the highest single abundances of taxa (Figure 1). Proportions of plant forms used by honey bees are consistent with the overall proportions of plant forms of problem weeds in reserves (Timmins and Williams,1987). Weed habits were herbs (28%), shrubs (35%), and trees (32%) and the remaining three species were vines.

A large proportion of the weeds in Table 1 are also considered important honey plants. Fifteen individual weed species found in PNAs in New Zealand are known as important sources of honey worldwide. Another 24 taxa belong to 10 important honey or honeydew producing genera (although these may not necessarily be useful for honey production at the species level). Of those, the genera *Pinus*, *Racosperma*, *Salix*, and *Berberis* contribute the majority. Over half of the taxa in Table 1 (57%) belong to important world honey or honeydew producing groups (after Crane, 1976).

Problem weeds

Only 22 species of the problem weeds potentially used by honey bees in Table 1 are specifically referenced as honey bee forage sources in New Zealand. However, other species not specifically cited may be visited. Some authors only mention generic nectar or pollen sources which could include the specific weeds: *Hieracium praealtum*, *Pinus contorta*, *P. nigra*, *P. pinaster*, and *Salix cinerea*. *Senecio mikanioides*, *Ligustrum lucidum*, and *Hakea salicifolia* belong to known honey producing genera and may be visited by honey bees in New Zealand. Also, as noted above, *Hedera helix* and *Rhamnus alaternus* are important world sources of honey (Crane, 1976) and honey bees are known to be the main pollinators of *Berberis darwinii* in New Zealand (Allen and Wilson, 1992). In total, 33 species of problem weeds are considered here to be potentially used by honey bees.

The problem weeds potentially used by honey bees are found in 13 families. Fabaceae, Pinaceae, and Asteraceae are the most prominent families comprising almost half of these weed species (18%, 15%, and 12%, respectively). Trees (33%) and shrubs (48%) are the most common habit of problem weeds utilised by honey bees. Herbs and vines comprise only 15% and 3%, respectively.

Reproduction of problem weeds potentially used by honey bees

Solely anemophilous (wind-pollinated) species account for 15% of problem weed species used by honey bees (*Pinus*, *Larix*). The nutritional value of pollen from Pinaceae is extremely low and honey bees will generally only harvest this type of pollen when no other sources are available (Bryant, 1982). No effect on plant reproduction by honey bees would be expected for members of Pinaceae. Of the weeds visited by animals, willows (Salicaceae) and heather (*Calluna vulgaris*) are also often wind-pollinated.

Self-pollination appears to be important in *Leucanthemum* (Knuth, 1908), *Calluna vulgaris* (Chapman, 1984; Gimingham, 1960), *Hakea gibbosa* (Peterson, 1935), and *Rubus* (Proctor and Yeo, 1973). Although the pollination mechanism still exists in *Hieracium* species, they are obligate apomicts requiring neither pollination nor fertilisation for seed production (Proctor and Yeo, 1973). *Rubus* is a partial apomict and requires pollination for sexual or apomictic reproduction (Proctor and Yeo, 1973).

The potential for vegetative spread of the weeds of Rosaceae, *Hieracium*, *Calluna*, *Salix fragilis*, and *Berberis darwinii* is high. Vegetative propagation of *Rubus* is extensive and survival of daughters produced vegetatively is higher than that for seedlings (Kigel and Koller, 1985). All plants of *S. fragilis* in New Zealand originate from the male clone (Moar, 1985; Webb *et al*., 1988) and with the exception of some hybridisation with other willows (Webb *et al*., 1988), vegetative propagation is the only mechanism for reproduction.

The weed species in Asteraceae, Rosaceae, Salicaceae, and *Calluna vulgaris* of Ericaceae were associated most obviously with a large variety of insect visitors, often from 3-4 orders (Table 2). With the exception of Ericaceae, the nectar of the members of these families and of *Acer pseudoplatanus*, *Hedera helix*, *Rhamnus alaternus* and that of Proteaceae is well-exposed or only partially concealed and is easily available to visitors. According to Knuth (1906), the members of the above European taxa are primarily adapted to pollination by short to medium tongued visitors. Also, even though the nectar of *C. vulgaris* is concealed, it is still easily available to visitors with short to medium size probosises. The Australian

Table 2: *List of visitors to entomophilous problem weeds potentially visited by honey bees in New Zealand Protected Natural Areas. Numbers refer to the sources of information, and letters to the visitor taxon. Sources are: 1= Knuth (1906, 1908, 1909), 2= Proctor and Yeo (1973), 3= Alan Mark (pers. comm.), 4= Colin Webb (pers. comm.), 5= Gimingham (1960), 6= Armstrong (1979), 7= P.A. Williams (*pers. comm.*). Visitors are: a= ant, b= bee, ltb= long-tongued bee, stb= short-tongued bee, w= wasp.*

	Coleoptera	Diptera	Hymenoptera	Lepidoptera	other
Aceraceae					
Acer pseudoplatanus		1;2	ltb,stb,w,b 1;2		
Araliaceae					
Hedera helix		1	w 1;2	1;2	
Asteraceae					
Hieracium pilosella	1	1;2;3	ltb,stb 1	1	
Hieracium praealtum		3			
Leucanthemum vulgare	1	1;2	ltb,stb,w 1;2	1	
Senecio mikanioides					
Berberidaceae					
Berberis darwinii			b,w 2		
Berberis glaucocarpa			b,w 2		
Caprifoliaceae				2	birds 2
Leycesteria formosa				4	
Ericaceae					
Calluna vulgaris		1;2;5	stb,ltb,w 1;2;5	2	Thysanoptera 1;2;5
Erica lusitanica			ltb 7		
Fabaceae			ltb 2		
Cytisus scoparius		1	stb,ltb 1	1	
Lotus pedunculatus		1	ltb 1	1	
Lupinus arboreus					
Racosperma dealbatum					
Robinia pseudacacia			ltb 1		
Ulex europaeus	1	1	stb,ltb 1;2		Thysanoptera 1
Oleaceae					
Ligustrum lucidum				4	
Ligustrum sinense				4	
Proteaceae					insects,birds,mammals
Hakea gibbosa			stb,w 6		
Hakea salicifolia			stb,w 6		
Hakea sericea		7	stb,w 6;7		
Rhamnaceae					
Rhamnus alaternus			b 1		
Rosaceae		2	2		
Crataegus monogyna		1;2	stb,ltb 1;2		
Rosa rubiginosa	1;2	1	ltb 1		
Rubus fruticosus agg.	1;2	1;2	ltb,stb,w,a 1	1;2	
Salicaceae		2	2	2	Hemiptera 2
Salix fragilis	1	1	stb,a 1		
Salix cinerea	1	1;2	stb,ltb,w 1	1	Hemiptera 1

genus *Hakea* (Proteaceae) is visited by short-tongued bees and wasps in Australia (Armstrong, 1979) and *H. sericea* is also known to be primarily visited by flies and bees in South Africa which are assumed to be major pollinators (P.A. Williams, *pers. comm.*). Pollination of the above groups is generally entomophilous and relatively unspecialized. Pollination of Fabaceae, on the other hand, tends to be associated with more specialized longer tongued bees, and *Berberis* with wasps and bees (Proctor and Yeo, 1972), especially honey bees in New Zealand for *B. darwinii* (Allen and Wilson, 1992). The problem weeds of the Oleaceae have classic moth-pollinated flower forms with corollas too deep for efficient pollination by honey bees. Flowers of *Leycesteria formosa* (Caprifoliaceae) also have flowers suggesting lepidopterous pollination (C.J. Webb, *pers. comm.*).

Table 3: *Reproductive mechanisms, visitor diversity, and flower morphology of entomophilous problem weeds potentially visited by honey bees in New Zealand Protected Natural Areas. Diversity of visitors: 1= >1 order or non-hymenopterans probably pollinate; 1.5= non-hymenopterans and hymenopterans are major pollinators (see text); 2= Hymenoptera is probably the major pollinator; 2.5= bees with intermediate tongue length are probably major pollinators; 3= longer-tongued bees are probably major pollinators. •= weed not cited for use by honey bees in New Zealand.*

	Potential for self-pollination or apomixis	Vegetative potential	Diversity of visitors	Availability of floral resource or flower shape
Aceraceae				
Acer pseudoplatanus	none		1	exposed
Araliaceae				
Hedera helix •	none		1	exposed
Asteraceae				
Hieracium pilosella	high	high	1	exposed
Hieracium praealtum •	high	high	1	exposed
Leucanthemum vulgare	high		1	exposed
Senecio mikanioides •				exposed
Berberidaceae				
Berberis darwinii •		high	2.5	partly concealed
Berberis glaucocarpa			2	partly concealed
Caprifoliaceae				
Leycesteria formosa			1	concealed
Ericaceae				
Calluna vulgaris	high	high	1	concealed
Erica lusitanica	high	low	3	
Fabaceae				
Cytisus scoparius	low	low	3	zygomorphic
Lotus pedunculatus	none	low	3	zygomorphic
Lupinus arboreus		low		zygomorphic
Racosperma dealbatum		low		zygomorphic
Robinia pseudacacia		low	3	zygomorphic
Ulex europaeus	none	low	2.5	zygomorphic
Oleaceae				
Ligustrum lucidum •			1	long corolla
Ligustrum sinense			1	long corolla
Proteaceae				
Hakea gibbosa	high		1.5	exposed
Hakea salicifolia •			1.5	exposed
Hakea sericea			1.5	exposed
Rhamnaceae				
Rhamnus alaternus •			2	exposed
Rosaceae				
Crataegus monogyna		high	1	partly concealed
Rosa rubiginosa		high	1	exposed
Rubus fruticosus agg.	high	high	1	concealed
Salicaceae				
Salix fragilis	low	high	1	partly concealed
Salix cinerea •	low		1	partly concealed

Importance of honey bees in problem weed reproduction

The influence of honey bees was considered to be ‘none’ for the strictly anemophilous plants (*Pinus*, *Larix*), the obligate apomictics (*Heiracium*), those only self-pollinated (*Hakea gibbosa*), and those reproducing only vegetatively (*Salix fragilis*). A ‘low level’ of influence was assumed for weeds with easily accessible floral resources and very diverse visitors (*Acer pseudoplatanus, Hedera helix, Hakea sericea, Hakea salicifolia, Leucanthemum vulgare, Rhamnus alaternus, Rosa rubiginosa, Salix cinerea* and *Senecio*) or probable major pollinators other

Table 4: *Relative importance of honey bees in the pollination or reproduction of problem weeds potentially visited by honey bees in New Zealand Protected Natural Areas.*

NONE	**LOW**
Pinus contorta	*Acer pseudoplatanus*
Pinus nigra	*Hakea salicifolia*
Pinus pinaster	*Hakea sericea*
Pinus radiata	*Helix hedera*
Hakea gibbosa	*Leucanthemum vulgare*
Hieracium pilosella	*Leycesteria formosa*
Hieracium praealtum	*Ligustrum lucidum*
Larix decidua	*Ligustrum sinense*
Salix fragilis	*Rhamnus alaternus*
	Rosa rubiginosa
	Salix cinerea
UNKNOWN	*Senecio mikanioides*
Erica lusitanica	
Berberis glaucocarpa	**MEDIUM**
Cytisus scoparius	*Calluna vulgaris*
Lotus pedunculatus	*Crataegus monogyna*
Lupinus arboreus	*Rubus fruticosus* agg.
Racosperma dealbatum	
Robinia pseudacacia	**HIGH**
Ulex europaeus	*Berberis darwinii*

than bees (*Leycesteria formosa, Ligustrum*). *Calluna vulgaris*, *Crataegus monogyna*, and *Rubus fructicosus* agg. were assigned a 'medium' level of influence because floral resources were not fully accessible to short-tongued insects but were visited by diverse vectors and had alternate mechanisms for reproduction. *Berberis darwinii* was given a 'high' level of influence because honey bees are main pollinators. Importance of honey bees in problem weed reproduction is summarised in Table 4.

Eight remaining weeds were not ranked. Little information exists to determine the level of influence of honey bees on these plants (all problem weeds of Fabaceae, *Erica lusitanica*, and *Berberis glaucocarpa*). We assume that honey bee reproductive influence on these species is medium-high because six of the eight species are in the Fabaceae which are mainly bee pollinated. The other two species are closely related to plants given medium or high assessments and honey bee influence on pollination may also be substantial. Because long-tongued bees are the primary visitors to the Fabaceae weeds, it is assumed that honey bees and/or bumble bees are important pollinators but their relative contribution to pollination is not known. Many Fabaceae have zygomorphic flowers which are typically "bumble bee type flowers" (Leppik, 1953). Honey bees will use these flowers but bumble bees may visit such flowers more than honey bees (Free, 1970). However, gorse (*Ulex europaeus*) is known to provide a very important pollen source for beekeepers (Hill and Sandrey, 1986) and low seed pod production in the Chatham Islands has been attributed to low populations of honey bees (McFarlane, Grindell and Dugdale, 1992). Of the bumble bees in New Zealand, only *Bombus terrestris* (L.) (a short-tongued species) visits gorse and no bumble bees exist on the Chatham Islands (McFarlane *et al*., 1992) to determine the relative importance of pollination by the two groups.

Discussion

A cursory examination of the surveyed weeds visited by honey bees in New Zealand PNAs, and the importance of many of these plants to honey production worldwide, suggests that honey bees may play a significant role in their propagation. Alternatively, importance of a weed species for honey production could also simply reflect a general abundance of the weed. Although this question is not resolved here, our assessment of weed reproduction and pollination indicates far fewer problem weeds are likely to have substantial reproductive advantages as a result of honey bee foraging. Strictly anemophilous species, autogamous species, obligate apomicts, or plants with only vegetative reproduction, are not influenced by honey bee foraging, although they account for almost a third (27%) of the problem weeds potentially used by bees in this study. The influence of honey bees on weed reproduction is probably minimal for the largest proportion of problem weeds (36%) potentially used by them and weeds with a medium level of reproductive influence by honey bees represent 9%. Only one of the problem weed species is known to be mainly pollinated by honey bees in New Zealand (3%). The remaining weeds (24%) could not be evaluated because we were unable to determine the relative importance of bumble bees and honey bees in their pollination, or no information was available.

Most native New Zealand flowers are small and simple (Lloyd, 1985) and the native pollinating bees and many other native insects have correspondingly short tongue lengths. The honey bee may be considered to have an intermediate tongue length allowing it to use plants within a wide range of floral morphologies with relative ease and efficiency. If the floral morphology of an introduced weed is such that short-tongued visitors are unable to effect pollination and pollination is required, honey bee pollination might be important in overall weed spread. However, if a plant requires pollination by a longer tongued bee, honey bee pollination may be less effective than that of the longer tongued bumblebees. Perhaps some problem weeds are optimally pollinated by bees of intermediate tongue length (e.g., gorse). If honey bees are the only pollinators present, their removal might help control seed set. However, the current bee fauna of New Zealand includes the short-tongued natives, the intermediate tongued honey bee and *Bombus terrrestris*, and the longer tongued *Bombus subterreneus*, *Bombus hortorum* and *Bombus ruderatus*. Therefore, the honey bee does not solely fill an "optimum" pollinating niche for intermediate-tongued bees. *B. terrestris* is also widespread and presumably uses many of the same flowers. Several long-tongued species and many short-tongued visitors can also efficiently use introduced plants with differing flower morphologies.

None of the problem weeds evaluated appear to have only one pollinator and although honey bees are, or may be, important pollinators of a few species, other native and introduced bees or other insects and birds may also be adequate pollinators. Native Colletidae (miner bees) and Halictidae (sweat bees) are known to visit many introduced flowers (Donovan, 1980), bumblebee foraging on introduced plants is extensive (McFarlane, 1976), and native birds are also known to visit introduced plants (reviewed in Godley, 1979). Consequently, restriction of honey bees in areas where most of the weed species discussed are problems would not eliminate pollination and/or further spread. It could, however, potentially reduce seed production if pollinators are limiting. Overall, pollination limitation appears unlikely given the mainly generalist pollination strategy of most weed species requiring pollination. For instance, *Calluna vulgaris* is apparently wind-pollinated or pollinated by thrips in the Faroe Islands where pollinating bees and many other pollinating insects are absent (Proctor and Yeo, 1973).

The focus of our review has been on the pollination and reproductive mechanisms of weedy plants. However, the success of some weeds may be largely due to other factors. For instance, the more vigorous growth of broom (*Cytisus scoparius*) in New Zealand compared to Europe has been attributed to the absence of its major invertebrate predators (Williams, 1981). Another example is *Berberis darwinii*. Although honey bees are main pollinators of *B. darwinii* in New Zealand, pollination may not be limiting. In this plant, flower production, pollination, seed production, fruit production, and dispersal success are all high (Allen and Wilson, 1992). Even in the absence of honey bees, this species would have considerable reproductive success using alternative pollinators. In fact, *B. darwinii* and nine other problem weeds are native to areas outside the natural range of the honey bee and have reproduced in their absence, using other pollinators or reproductive mechanisms. Weed success is also not simply a function of reproductive and growth dynamics or release from antagonists. Weed invasion is prone in disturbed environments (reviewed in Bergelson, Newman and Floresroux, 1993) and problem weeds tend not to substantially invade intact native forest in New Zealand (Timmins and Williams, 1987). The fragmentation of some New Zealand forests is extensive and edge effects are changing microclimate and vegetation (Young and Mitchell, 1994), and this has a dramatic influence on the susceptibility of native forest to weed invasion (Timmins and Williams, 1991). Another major factor in weed success is often a specialised dispersal mechanism allowing entry to disturbed areas (Timmins and Williams, 1987).

From the results of this overview, we conclude that the honey bee is probably not an important factor in the abundance and spread of the majority of problem weeds possibly visited by them in New Zealand PNAs. However, experimental evidence is largely lacking. We suggest the avenues for further research should be directed toward determining whether seed production in the species likely to be influenced by honey bee foraging is dramatically increased in the presence or decreased in the absence of honey bees and, if so, at what hive densities? An assessment of the extent to which managed honey bees might increase pollination would require quantifying the level of feral populations in and near PNAs. It is also important to determine whether other native or introduced bees could fulfill plant pollination requirements if honey bees were eliminated. If honey bees are shown to dramatically increase seed set of some problem weeds, it would be necessary to provide evidence that the level of seed set is a major factor in the weed's abundance in PNAs. No studies have shown increased weed abundances as a result of increased pollination in New Zealand. If other factors such as those outlined above are limiting weed abundances, pollination plays a minor role.

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Appendix overleaf

Appendix 1: *References citing honey bee use of the weed flora surveyed in New Zealand PNAs (after Williams and Timmins, 1990).*

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