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A review of New Zealand's deliberately introduced bee fauna: current status and potential impacts

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ABSTRACT

Eight bee species have been deliberately released into New Zealand since the 1830's. The honey bee (*Apis mellifera* L.) was introduced primarily for honey production but has become the most important insect pollinator of seed, vegetable, fruit crops and pastures. The remaining species (*Bombus terrestris* (L.), *B. hortorum* (L.), *B. ruderatus* (F.), *B. subterraneus* (L.), *Megachile rotundata* (F.), *Nomia melanderi* (Cockerell), *Osmia coerulescens* (L.) were introduced to pollinate either red clover (*Trifolium pratense*) or lucerne (*Medicago sativa*). The honey bee has almost exclusively been relied upon for crop pollination although species of *Bombus* and *M. rotundata* are occasionally used commercially. The spread throughout New Zealand of the *varroa* mite (*Varroa destructor* Anderson & Trueman), a parasite that exclusively kills honey bees, has increased the cost of managing honey bee hives. The use of alternative bee species for crop pollination may reduce the potential impact of factors influencing the availability and cost of honey bee pollination services. However, consideration must be given to the potential impact that expanding populations of introduced bees could have on native and exotic flora and fauna. This review examines the current and potential use of the eight deliberately introduced bee species in New Zealand, their distribution, and potential impact on New Zealand's biota.

KEYWORDS

Pollination, *Varroa*, *Apis*, bee competition, agroecosystems.

INTRODUCTION

With the advent of agriculture, a huge variety of plant species have been deliberately spread throughout the world for cultivation. Many of these plants require insect pollination to produce fruit and seed (Free 1993; Delaplane & Mayer 2000). To achieve this, bees have been introduced to ensure adequate crop pollination. In many countries, the honey bee (*Apis mellifera*) is heavily relied on to pollinate a wide variety of crops (Free 1993; Delaplane & Mayer 2000), but introductions of other bee species for crop pollination, particularly *Bombus terrestris* and *Megachile rotundata*, have seen them become widespread throughout the world (Goulson 2005). More recently, the impact of pests and diseases on honey bee populations has increased concern regarding the future production of insect pollinated crops (Cunningham *et al*. 2002; Cox-Foster *et al*. 2007). Consequently, there has been focus on the potential value of other insects as crop pollinators (Rader *et al*. 2009). Conversely, there is concern that introduced bees may have an impact on native bee and other pollinating species, and the reproduction of native plants and weeds (Goulson 2003; 2005).

Of the 40 species of bee within New Zealand's biogeographical region (Donovan & Maynard 2010), 13 have arrived since European settlement (Donovan 2007) with 8 having been deliberately introduced to aid crop pollination. They are the honey bee *Apis mellifera* (L.), the bumble bees: *Bombus terrestris* (L.), *B. subterraneus* (L.), *B. ruderatus* (F.) and *B. hortorum* (L.); the lucerne leafcutting bee: *Megachile rotundata* (F.); the alkali bee: *Nomia melanderi* (Cockerell) and the red clover mason bee *Osmia coerulescens* (L.). All of the species, except for *Osmia,* have become naturalised, but their abundance, distribution and current value to crop pollination vary greatly.

A review of the purposely introduced bee species to New Zealand is timely. The establishment of the *varroa* mite in New Zealand in 2000 (Zhang 2000) is predicted to have an economic impact of \$365 - \$661 million between the period 2003 to 2028 (Anon. 2002) and between \$198 and \$433 million dollars in the South Island alone (Simpson 2003). Much of this cost has been associated with the potential disruption of honey bee pollination of crops and pastures and the increased costs associated with managing the *varroa* mite within honey bee hives (Simpson 2003). An examination of the potential use of alternative bees, including introduced species, may lead to the development of alternative or supporting pollination services to the honey bee. However, consideration must also be given to the potential impacts that larger and more widespread populations of introduced bees could have on native and introduced flora and fauna.

This paper reviews the eight purposely introduced bee species in New Zealand by outlining their origin and introduction, distribution and preferred habitat, management, benefits and limitations as managed pollinators and potential impact on native bee species. The potential use of these bee species as crop pollinators in New Zealand, their likely impact on native and introduced flora and the possibility of introducing new bee species is then discussed.

Apis mellifera

Origin and Introduction

The honey bee was first introduced from England into the North Island of New Zealand in 1839 (Donovan & Macfarlane 1984; Barrett 1996). Their introduction into the South Island from Australia occurred in 1842 (Donovan 2007). Since then, many additional introductions from various locations worldwide have been made (Barrett 1996).

Distribution and preferred habitat

Honey bees are found almost throughout the entire New Zealand geographical region, including many offshore islands (Donovan 2007). The favourable climatic conditions, their ability and willingness to forage on a vast number of native and introduced plant species, the availability of sites favourable for nesting and, until recently, the absence of serious pests and diseases, have ensured the success of feral colonies (Donovan 2007). Prior to the arrival of varroa, feral honey bee numbers had been estimated at about 200,000 colonies, however, the population of feral honey bees in the North Island is believed to have been decimated due to the mite and a similar impact is expected in the South Island (Donovan 2007).

Management

The honey bee has been managed by humans for thousands of years for the provision of honey and the pollination of crops (Delaplane & Mayer 2000). During this time improvements in hive design and selective breeding of bees has provided easier management techniques and improved their flexibility as crop pollinators (Delaplane & Mayer 2000). Man-made hives normally contains several thousand bees (Free 1993) and their design allows for easy transport over large distances (>1000 km) (Benjamin 2008). A detailed review on honey bee management and their use as pollinators for common crop species is provided by Free (1993) and Delaplane & Mayer (2000).

Benefits and limitations as managed pollinators

For most crops the honey bee remains the most cost effective and reliable pollinator. They also provide significant pollination services to crops for which they are considered relatively inefficient pollinators such as red clover and lucerne (*Medicago sativa* L.) (Free 1993). This is because honey bees will forage upon many crop species (Delaplane & Mayer 2000; Cunningham *et al*. 2002) and hives (containing thousands of bees) can easily be transported to selected fields (Benjamin 2008). However, a myriad of honey bee pests, diseases and Colony Collapse Disorder have negatively impacted honey bee populations around the world (Cox-Foster *et al*. 2007). In New Zealand, miticides must be used to control the varroa mite within hives, otherwise colonies will collapse.

Impact on native bee species

Honey bees are known to affect the foraging behaviour of native fauna on flowers elsewhere in the world (Butz Huryn 1997). Examples include the foraging activity of native bees on *Melastoma affine* D. Don. (Gross 2001) and bumblebees on *Phacelia tanacetifolia* (Walther-Hellwig *et al*. 2006). However, acquiring evidence demonstrating the possible impact of introduced honey bees (and other bee species) on the abundance of other pollinators is problematic due to the difficulty of conducting appropriate experiments (Goulson 2003). For example, observation data recording bee abundance on plants may not accurately reflect the abundance of colonies because the activity of different species can be affected by climate, floral preferences and the location of plant species in the environment (Thomson 2006).

To our knowledge, specific experiments to evaluate the impact of honey bees on the abundance and occurrence of native pollinators have not been conducted in New Zealand. In New Zealand, honey bees forage on a vast number of native and introduced plant species (Butz Huryn 1995; Donovan 2007), suggesting the potential for competition with native flower visitors for floral resources. While acknowledging the potential for floral resource competition, Donovan (1980) concluded that anthropogenic factors, such as land disturbance through agriculture and the removal of native vegetation, are more likely to influence native bee abundance than competition with honey bees. Several native bees species have also been observed exploiting pollen and nectar resources alongside honey bees on introduced plants such as onion and *Brassica rapa* (Howlett *et al.* 2005; 2009a). Competition for nesting sites does not occur as native species are ground nesting (*Leoiproctus* and *Lasioglossum* spp.) or nest within the hollows of plant material (e.g. *Hylaeus* spp.) (Donovan 2007).

Bombus spp.

Origin and Introduction

Bumble bee species were purposely introduced from Britain to New Zealand primarily to aid in the pollination of red clover (*Trifolium pratense* L.) (Donovan 1980; Donovan & Macfarlane 1984). Of the four species established in New Zealand, three are long-tongued (*B. hortorum*, *B. ruderatus* and *B. subterraneus*) while *B. terrestris* is short-tongued (Donovan 1980; Donovan & Macfarlane 1984).

The first successful introduction of *Bombus* into New Zealand from England was near Christchurch in 1885 (Farr 1889) with a further successful introduction, again from England, approximately 20 km south-east of Christchurch in 1906 (Hopkins 1914). In each case, the introduced species were not recorded with certainty (Macfarlane & Gurr 1995) and it was not until 1964 that the four species were correctly identified (Gurr 1964).

Subsequent introductions of undetermined species of *Bombus* from the South to the North Island occurred in 1887 (Thomson 1922) and onwards, with *B. terrestris* and *B. ruderatus* establishing (Macfarlane & Gurr 1995). *B. hortorum* was successfully introduced to the North Island in 1965 while attempts to introduce *B. subterraneus* from the South Island have failed (Gurr 1972).

Distribution and preferred habitat

The spread of each bumble bee species throughout New Zealand has been variable. *Bombus terrestris* has become the most abundant species and is found throughout New Zealand below the subalpine zone (Macfarlane & Gurr 1995). Its willingness to forage on more plant species, and over a greater geographic range, allows a greater exploitation of habitat types compared with the long-tongued species (Goulson & Hanley 2004).

Bombus ruderatus is the most widespread long-tongued bumble bee and is most abundant in lightly settled, drier and warmer districts (Macfarlane & Gurr 1995). *Bombus hortorum* is found from the lower North Island (from Palmerston North south) and throughout much of the South Island with the exception of the north Canterbury region and the west coast (Macfarlane & Gurr 1995). Evidence indicates that *B. hortorum* had increased its range between 1964 and 1993 in both the North and South Island but appears restricted to cooler moister districts (Macfarlane & Gurr 1995). *Bombus subterraneus* appears restricted to the central South Island (Macfarlane & Gurr 1995), particularly around lake margins (Goulson & Hanley 2004; Goulson *et al.* 2006) and the population may be declining (Howlett *et al*. 2009b). *Bombus hortorum* and *B. ruderatus* have been found near road verges, shingle river margins, improved pasture and non-native scrub (Goulson *et al.* 2006).

Management

Commercial colonies of *B. terrestris* are used to pollinate glasshouse crops such as tomatoes (Dafni 1998; Horticulture New Zealand 2005) while long-tongued *Bombus* species are trap nested (trap nest boxes or domiciles placed in the environment to trap founding colonies) and sold to supply pollination services to red clover (Donovan 2001).

Domiciles (man-made nesting boxes) have been developed and employed to increase bumble bee abundance in agroecosystems (Donovan & Wier 1978; Pomeroy 1981; Macfarlane *et al*. 1983; 1984; Barron *et al*. 2000) and occupancy was found to increase over consecutive years (Donovan & Weir 1978; Pomeroy 1981; Barron *et al*. 2000). Long-tongued bumble bees species, particularly *B. ruderatus*, were found to be the most common colonists (Macfarlane *et al*. 1984; Barron *et al*. 2000). Domicile placement was found to be an important factor influencing bee occupation; those placed near greater floral resources and at sites of lower agricultural intensification attracted significantly more founding bees (Barron *et al*. 2000).

Benefits and limitations as managed pollinators

Bumble bees are efficient pollinators of many flowering fruit, vegetable and seed crops grown in New Zealand including kiwifruit (*Actinidia deliciosa*) (Macfarlane & Ferguson 1983; Read *et al.* 1989; Pomeroy & Fisher 2002), blueberries (*Vaccinium corymbosum*) (Macfarlane 1992), white clover (*Trifolium repens*) (Forster 1974), red clover (*T. pratense*) (Macfarlane & Griffin 1985; Macfarlane *et al*. 1991; Donovan 2001), lucerne (*M. sativa*) (Gurr 1974), kale (*Brassica oleracea*) (Forster *et al.* 1973) and pak choi (*Brassica rapa*) (Rader *et al*. 2009).

The long-tongued species are significantly better pollinators of broad beans (*Vicia faba*) and red clover than honey bees due to their ability to access the base of the corolla tubes (Free 1993). In contrast, the short-tongued *B. terrestris* can be detrimental to the effective pollination of these crops by biting holes at the base of the corollas and robbing flowers of nectar (Free 1993). However, it is still regarded as an important pollinator of red clover (Forster & Hadfield 1958).

Bumblebees can also forage at lower temperatures than most other bees, making them useful pollinators during prolonged cool periods (Free 1993). They also forage over a greater diurnal range than honeybees (Fussell 1992).

The value of unmanaged bumble bees to crop pollination is currently restricted by their unpredictable abundance within the agricultural landscape. In New Zealand, their occurrence and abundance can vary significantly within and between regions (Howlett *et al.* 2005), but a South Island study conducted on flowering white clover on road verges suggests they are relatively common throughout the island in pastural areas (Howlett *et al*. 2009c).

B. terrestris is used commercially in New Zealand for the pollination of covered crops such as tomatoes. Commercial bumblebee colonies contain only a few hundred workers, (as opposed to the thousands normally found within a honey bee hive) making them more amenable for the pollination of enclosed crops confined within a small area. However, for crops grown in the open, honey bees remain the preferred and cheaper option.

Although the use of domiciles could assist in increasing bumblebee numbers within crops, they cannot currently be relied upon to provide predictable populations. Occupancy of domiciles can vary substantially. Pomeroy (1981) recorded bumble bee occupancy rates of 93% for plastic roofed domiciles with underground entrances and an earth floor. In contrast, Barron *et al*. (2000) recording relatively low bee occupancy for above ground, plywood domiciles (12.75% for the high floral resource, less intensively farmed sites). Further work is needed to evaluate domicile design and to identify and reduce factors limiting bee occupancy if they are to assist in building large predictable bumble bee populations.

Impact on native bee species

The impact of the introduced bumblebee species on native bee species in New Zealand is poorly understood. However, elsewhere in the world the introduction of bumblebees, particularly *B. terrestris* has affected native bee species. In Japan, *Bombus terrestris* has been implicated in declining numbers of overwintering *B. hypocrita sapporoensis* (Cockerell (*Bombus* s. str.)) queens due to competition for nesting sites (Inoue *et al*. 2008). Moreover, the robbing of *Corydalis ambigua* nectar by *B. terrestris* is believed to have caused a reduction in the number of flowers visited by the more effective pollinator *Bombus ardens*, which has resulted in poorer fruit set (Dohzono *et al*. 2008). In the United Kingdom there is concern that imported *B. terrestris* could out-compete native *B. terrestris* due to their substantially higher nectar foraging rates as measured in four of five locations (Ings *et al*. 2006).

In New Zealand *B. terrestris* is the only *Bombus* species that readily forages on a range of native plants with individuals observed on 47 native plant species (Donovan 2007). It may therefore compete with native species for nectar and pollen from a range of plant species. In contrast *B. ruderatus* was observed foraging on only three native plant species (*Fuchsia exorticata*, *Sophora microphylla*, *Hebe loganioides*) and *B. hortorum* on one (*Clianthus puniceus*) (Donovan 2007). *Bombus subterraneus* has not been observed visiting any native plant species. *Trifolium pratense* and *Echium vulgare* have been noted as the predominant plant species visited by the long-tongued species (Goulson & Hanley 2004) along with *Lupinus* spp. for *B. subterraneus* (Donovan 2007).

Megachile rotundata

Origin and Introduction

The lucerne leafcutting bee is a solitary bee native to Eurasia. It was first introduced into New Zealand from North America in 1971 (Donovan *et al.* 1982) to assist in the pollination of lucerne (Donovan & Macfarlane 1984).

Distribution and preferred habitat

Wild lucerne leafcutting bees have not become abundant in New Zealand, even though managed hives are annually placed within lucerne crops, particularly in the Canterbury district. Although few collections have been made, wild bees have been identified from Central Canterbury, Central Otago and Marlborough in the South Island and have been found nesting in both man-made and natural cavities in Marlborough (Donovan 2007).

The bee is used as an efficient lucerne pollinator in the United States and Canada where large populations are managed effectively (Donovan & Macfarlane 1984), but some aspects of New Zealand's environment (particularly wind, changeable weather and the occurrence of the parasitoid *Melittobia* spp.) can be detrimental to bee performance. As a result, hives should be positioned to minimise exposure to wind and rain; predators identified and controlled, and hive placements timed to maximise pollination and cell development (Read & Donovan 1984).

Management

M. rotundata is one of few commercially managed bee species used for crop pollination in New Zealand (Donovan & Macfarlane 1984). It is one of the easier species to manage due to its gregarious nature and its readiness to nest in artificial hives (Read & Donovan 1984). Between 1971 and 1984, 875,000 cells were imported into New Zealand and in 1984 the bee population was estimated at five million (Read & Donovan 1984). A programme was established by the Department of Scientific and Industrial Research to educate bee keepers to maximise the efficient use of the species. However, the programme ceased after 1992 with the disestablishment of the Department and bee numbers subsequently collapsed (Donovan 2007). In 2009, the number of managed (overwintered) *M. rotundata* was estimated to be less than 100,000 (Ron Van Toor pers. comm.), just enough to pollinate a few hectares of lucerne annually.

Benefits and limitations as crop pollinators

The lucerne leafcutting bee has been described as an effective pollinator of several crops including white and red clover (Richards 1991), carrot (Tepedino 1997) and *Brassica rapa* (Fairey & Lefkovitch 1991). As it is one of very few species that can be managed and supplied in large numbers and can be easily transported to fields, it could potentially be used as an alternative or support pollinator to the honey bee for a variety of crops in New Zealand. However, lucerne leaf cutting bees require warm temperatures (>16°C) when conditions are sunny with little wind before they actively forage on crops. Therefore they are likely to be inconsistent in their effectiveness in pollinating crops located in cool and windy locations (Donovan & Macfarlane 1984).

Impact on native bee species

In New Zealand, bees have been observed foraging on 10 different introduced plant species from the families Asteraceae, Brassicaceae, Crassulaceae and Fabaceae (Donovan 2007). Although competition for nesting sites may occur with the native *Hylaeus* species that may also use similar cavities for nesting, their low abundance, restricted distribution and apparent preferences for introduced plants suggest they are unlikely to pose a competitive threat to native pollinators.

Nomia melanderi

Origin and Introduction

The alkali bee is a solitary ground nesting bee and was first introduced into New Zealand from western North America in 1964 to aid in the pollination of lucerne (Donovan 1979). It is not currently managed commercially for crop pollination.

Distribution and preferred habitat

In New Zealand, the alkali bee is restricted to the Marlborough District (north-east South Island) at Dillons Point (Donovan & Macfarlane 1984) and to a man-made nesting site in the Wairau Valley (Donovan 2007). Bees have previously been introduced and observed nesting under natural conditions at Lake Ellesmere in the Canterbury district and under man-made conditions in several other locations in Central Otago, Canterbury, Marlborough (South Island) and at Manunui (central-western North Island). However, there is no evidence that any of these populations have persisted (Donovan 2007). In North America, the bee is found in locations where summer sunshine hours are high, and temperatures exceed 20ºC (Donovan 1979). Bees are also normally found in saline areas where salt has formed a crust layer near the surface of the soil and where moisture levels are maintained between 25 and 41 centibars (Donovan & Macfarlane 1984). Due to these specific factors, and New Zealand's relatively cool climate, alkali bees are unlikely to spread beyond a very limited range without direct intervention.

Management

In North America, artificial nest sites have been successfully developed allowing for the expansion of bee populations into areas where they previously have not occurred (Donovan & Macfarlane 1984). The development of a new nesting site involves the preparation of a nesting bed and then the transfer and burial of pre-pupating bees contained within soil cores (Donovan & Macfarlane 1984; Cane 2008). The alkali bee requires a moist silty soil with good hydraulic conductivity, and a surface free of vegetation that is periodically sealed with a salty crust (Cane 2008). Suitable nest site conditions can be created by irrigating soil using moats or buried perforated pipes (Cane 2008). To establish new colonies, soil cores containing alkali bee pre-pupae are dug from existing nesting sites during winter and positioned at a similar soil depth at the new site (Donovan & Macfarlane 1984).

Benefits and limitations as crop pollinators

In North America, the growing of lucerne seed crops has been correlated with increasing populations of alkali bees and subsequently, greater seed production (Donovan & Macfarlane 1984). However, in New Zealand, the potential use of the alkali bee as a crop pollinator appears restricted to the warmer regions of New Zealand (Donovan & Macfarlane 1984). In these regions, the potential development of the alkali bee as an effective additional or alternative pollinator to the honey bee for some crops, particularly clover, remains a possibility but requires further research.

Impact on native bee species

In New Zealand, alkali bees have been observed visiting the flowers of only five introduced plant species, all from the Asteraceae and Fabaceae (Donovan 2007). This suggests they are unlikely to significantly compete for floral resources with native species. However, they can visit the flowers of a broader range of species. Elsewhere, they have been observed foraging on or collecting pollen from a variety of plants including onion (Nye *et al.* 1973), sweet clover (*Melilotus alba* Desr.), yellow melilot (*M. officinalis* L.) and black mustard (*Brassica nigra* Koch) (Packer 1972).

Alkali bees have specific nesting requirements (and need warm sunny weather) which has undoubtedly restricted their spread throughout New Zealand. Their nesting requirements do not match those of native bee species and therefore competition for nesting sites is highly unlikely.

Osmia coerulescens

Origin and Introduction

The red clover mason bee is a native of Europe and Western Asia and was introduced into New Zealand with the aim of developing a manageable efficient pollinator of herbage seed crops such as red clover (Purves *et al*. 1998).

Distribution and preferred habitat

Although it may have the potential to colonise the drier areas of New Zealand, there has been no recording of it having naturalised (Donovan 2007).

Management

It is another bee species that can be managed using artificial nests (Dochkova 1995), but in 2009, there were fewer than 100 managed cells of red clover mason bee in New Zealand (Donovan unpublished data).

Benefits and limitations as crop pollinators

The red clover mason bee has not yet become of any economic importance in New Zealand (Donovan 2007). Bee numbers are currently low and research has been focussed on improving husbandry techniques to build the population (Donovan 2007). The parasitoid *Melittobia* spp. has caused high mortality of developing bees, subsequently preventing an increase in numbers in New Zealand (Purves *et al*. 1998). Elsewhere it has been noted as an important pollinator of red clover (Parker 1981), lucerne, bird's foot trefoil (*Lotus corniculatus*) sainfoin (*Onobrychis sativa*), (Dochkova 1995), and will forage and reproduce on a diet of white clover (Purves *et al*. 1998).

Impact on native bee species

The red clover mason bee has proven difficult to establish in New Zealand and currently poses no competitive threat to native bees. The bee could potentially compete with native bees for floral resources as it visits the flowers of a range of species (Tasei 1976), however, in New Zealand the bee has been observed foraging on only five introduced plant species, all from the Fabaceae (Donovan 2007). The bee also prefers to nest in pre-established cavities (Ruszkowski *et al*. 1995; Vicens *et al*. 1993) limiting its potential as a competitor with native bee species for nesting sites.

DISCUSSION

The potential use of introduced bees as crop pollinators

Nearly all industries that require pollination services for the production of economically viable crop yields remain solely reliant on the honey bee for pollination. However, the recent introduction and spread of the varroa mite throughout New Zealand highlights the vulnerability of these industries should honey bee pollination services become unavailable through the loss of honey bees.

The more manageable bees such as *Bombus* and *M. rotundata* offer the greatest scope as alternative or supporting pollinators to the honey bee in New Zealand. Research has already demonstrated that bumble bees will nest in man-made boxes under New Zealand conditions (Donovan & Weir 1978; Pomeroy 1981; Macfarlane *et al*. 1983; 1984; Barron *et al*. 2000). Further research to determine the requirements needed to maximise bumble bee abundance and better box design could increase their abundance within agroecosystems and increase their availability for crop pollination. The major factors currently limiting the use of *M. rotundata* as a crop pollinator are low bee numbers, its inactivity at temperatures less than 16°C or in windy conditions and a lack of research into its pollination efficiency for a range of crops.

The remaining bee species may also offer potential as crop pollinators, but substantial research is required to evaluate management possibilities, overcome limitations to their widespread establishment and abundance in New Zealand agroecosystems, and evaluate pollination efficiency and effectiveness under New Zealand conditions.

Introduced bees and competition with native bees

Very little research examining the impact of purposely introduced bees on native pollinating species in New Zealand has been conducted. In New Zealand, honey bees and *B. terrestris* are the most likely candidates to compete for floral resources with native flower visitors. However, any competition from honey bees is likely to be substantially reduced as populations (particularly feral) decline with the spread of *varroa* through the main islands. New Zealand flower visitors have been described as mainly polylectic (Lloyd 1985), exploiting many plant species including exotics (Donovan 2007). Competitive exclusion of native flower visitors by introduced bees from a particular plant is therefore likely to lead to their utilisation of less preferred plants (Goulson 2003).

Unintentionally introduced bee species may pose a greater threat to native pollinators. The male of the wool-carder bee (*Anthidium manicatum* L.) is an aggressive defender of territory and can kill other bee species (Donovan 2007). The bee was first reported in New Zealand in 2005 and has been found in both North and South Islands. Because of its recent arrival in New Zealand, its potential impact on New Zealand's biota, the possible extent of its range and its potential abundance have not been ascertained. Without strict quarantine procedures, unintentionally released bees also pose a threat for the possible introduction of parasites and pathogens that could affect native and introduced biota.

Introduced bees and their interaction with flora

The impact of introduced bees on native and introduced flora has not been studied extensively in New Zealand. A study conducted in Tongariro National Park (North Island) suggests that honey bees visiting native plants can reduce the abundance and diversity of dipteran visitors which may impact plant pollination (Murphy & Robertson 2000). Elsewhere, introduced bees can influence the pollination success of plants (Dafni 1998; Gross & Mackay 1998), and foraging preferences for specific plant species within an ecosystem could alter the structure of plant communities (Butz Huryn 1997). The large diversity of pollinators associated with many New Zealand native plants may reduce the potential selective effects caused by honey bee flower visitation, however, there is a need for further studies to verify the impacts of honey bees on native flora (Butz Huryn 1995).

The abundance of weeds that are favoured and efficiently pollinated by introduced bees may also be affected. In New Zealand, Goulson (2003 and references within) notes four major weeds − *Berberis darwinii* (barberry shrub), *Lupinus arboreus* (tree lupin), *Cytisus scoparius* (broom), *Ulex europeaus* (gorse) − that are primarily pollinated by *Bombus* or *Apis*. However, the role of introduced bees in the abundance and distribution of weed species is complicated by factors such as the plasticity of the breeding systems of many weeds (including self and unspecialised pollination, high germination potential and mechanisms for widespread seed dispersal), the ability of weeds to colonise habitats, and their escape from natural regulators within their environment of origin (Butz Huryn & Moller 1995 and references within).

Introduction of new bee species

New Zealand has strict guidelines associated with the introduction of new organisms to help prevent or manage adverse effects associated with their release. The guidelines have been further tightened with the passing of the HSNO (Hazardous Substances and New Organisms) act in 1996 (further amended in 2003). The potential benefits associated with the release of a new species must significantly outweigh the costs, including the impact on native and valued introduced biota, ecosystems, public health, Maori and their culture and traditions, the economy and New Zealand's international obligations (Anon. 2001). Although a number of bee species have been identified as potentially useful crop pollinators (Donovan 1990) and some of these species may meet the guidelines required for introduction, we know of no plans to introduce new species to New Zealand. There is still much to be learnt about the native and introduced bee species already present in New Zealand, particularly regarding their interaction with ecosystems. Research focussed on utilising them more effectively within New Zealand's agroecosystems may lead to more robust and integrated pollination systems that provide more efficient and predictable pollination services.

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