Bumblebees: implications of a new super-pollinator in mainland Australia

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Summary  Large feral populations of the European honey bee have been present in the Australian environment for at least 150 years and it is now impossible to evaluate the impacts these bees have had on our flora, native or introduced. Honey bees are efficient pollinators but some groups, especially Boraginaceae, Lamiaceae and Fabaceae, are more efficiently pollinated by bumblebees, either because of their weight, which allows them to ‘trip’ the flower, giving the bee access to the nectar but also releasing pollen onto the bee, or as ‘buzz’ pollinators, where they shake out pollen enclosed inside a pollen cone.

The European large earth bumblebee Bombus terrestris has been introduced into many countries worldwide by horticulturists in order to improve fruit set in greenhouse crops. Feral populations of B. terrestris are established in Japan, Chile, New Zealand and Tasmania. It is inevitable that the bumblebee will reach mainland Australia and establish feral populations here. This paper reviews the world literature on B. terrestris, considers probable impacts on seed production in weedy plants and proposes research to monitor and evaluate these impacts.

Keywords  Invasives, pollination, weed spread.

INTRODUCTION  The European honey bee Apis mellifera L. has been widespread in Australia for at least 150 years and has had a major impact here as elsewhere, reducing nectar availability for native bees, birds and nectar-feeding possums and gliders (Paton 1993, NSW Scientific Committee 2000, Kato and Kawakita 2004). It is also an important pollinator for introduced weedy plants and for crop plants including many tree crops (Hanley and Goulson 2003). The European large earth bumblebee Bombus terrestris (L.) was introduced to New Zealand last century and is now widespread there, but was never introduced to Australia.

Although never legally introduced to Australia, feral populations of B. terrestris were first found in Hobart, Tasmania in 1992 (Semmens et al. 1993), presumably originating from females from New Zealand. They have since spread throughout much of Tasmania including off-shore islands and national parks (Hingston et al. 2006). There is pressure from horticulturists to import B. terrestris into mainland Australia for use in pollinating glasshouse crops (Cooke 2001, Carruthers 2004), and a proposal for the importation of the species is currently waiting a decision from the Department of Environment and Heritage (AHGA 2005).

Given this pressure, and the extensive movements of people, vehicles and cargo from Tasmania to the mainland, it seems inevitable that bumblebees will soon arrive in the mainland through accidental or deliberate spread. The Tasmanian experience also strongly suggests that the species will spread rapidly throughout temperate Australia, although its northern climatic limitations are not well understood. It is therefore important that all involved in weed management be made aware of the implications.

Scientific interest in the bumblebee invasion has concentrated to date on the probable impact on Australian native fauna, primarily native bees and other nectar-feeding animals (Hingston and McQuillan 1999, Stout and Goulson 2000, Goulson et al. 2002). At least one study also considered impacts on pollination of native plants such as eucalypts (Hingston et al. 2006). This paper reviews possible impacts of the spread of the large earth bumblebee on the management of current and future invasive plants in Australia.

BUMBLEBEE IMPACTS

Native range and life history  The native range of B. terrestris is centred in Europe and North Africa, where there are several distinct populations with different colour forms (Goulson 2003, Ings et al. 2005). Feral populations are now established in Chile, Argentina, Israel, New Zealand and Japan (Hanley and Goulson 2003, Matsumura et al. 2004) as well as Tasmania.

Bombus terrestris is a large (20–35 mm long) ground-nesting bee which forms colonies producing up to 1000 progeny in a single season (Hingston et al. 2006). Colonies do not survive over winter in most regions, re-establishing each spring from a single queen (AHGA 2005). A recent study in Italy (Intoppa and Piazza 1998) found that Bombus
species chiefly visited flowers of the following families: Boraginaceae (Anchusa and Echium); Asteraceae (Carduus, Centaurea, Cirsium, Inula, Onopordum and Scolymus); Dipsacaceae (Dipsacus and Lomelosia); Lamiales (Ballota, Lamium, Phlomis, Satureja, Stachys and Teucrium); Fabaceae (Astragalus, Hedysarum, Lathyrus, Melilotus, Onobrychis, Trifolium and Vicia); Malvaceae (Malva); Onagraceae (Epilobium); and Scrophulariaceae (Digitalis).

Pollinator efficiency Honey bees are generally efficient pollinators and are important pollinators of crop and other species in Australia and world-wide (Hanley and Goulson 2003). However, some plant families, especially Fabaceae, Boraginaceae and Lamiales, are more efficiently pollinated by bumblebees. Papilionicaceous flowers, for example, have fused keel petals that protect the style and anthers through a ‘trip’ mechanism. B. terrestris adults are large enough to push the keel down thereby releasing the style and anthers to spring up in an explosive action and release pollen onto the back of the bee. Further, B. terrestris adults are very efficient ‘buzz’ pollinators, using a vibrating motion of their body to shake out pollen that is enclosed inside a pollen cone or androecium found in some plant groups (Parker 1997). This pollination is far more efficient for tomatoes in particular (AHGA 2005) and probably for other Solanaceae with similar flowers. For these reasons B. terrestris has been introduced into many countries by horticulturists. It can be readily reared in small colonies and is used in greenhouse systems to improve pollination and thereby fruit set in crops such as tomatoes, eggplant (both Solanaceae) and cucumber (Cucurbitaceae) (AHGA 2005).

Impacts on invasive plants Invasive weedy plants are already a major economic and environmental problem in Australia (Martin 2003, Sinden et al. 2004). New invasive plants are discovered at a rate of at least 15 each year (Groves and Hosking 1998). How many of these species are pollinator or seed limited is not generally known. For some, there is evidence that seed production is far more efficient than that theoretically needed for replacement (e.g. Sheppard et al. 2002), therefore any increase would not increase impact. Yet it has been clearly demonstrated that propagation pressure is a major factor influencing invasiveness and, therefore, spread rates (Von Holle and Simberloff 2005, Lambinos 2006).

For some existing weeds, very high seed production resulting in dense seedling establishment is known to increase initial competitiveness with existing vegetation (Navic et al. 2004). There may be other weed species where increased seed production would result in high initial competitiveness and significantly worsen the overall weed problem. High seed production also leads to very large soil seed banks, which increase the costs of management or control. For most weedy plants, therefore, increased seed production is highly likely to increase both their impact and the cost and difficulties of control.

However the extent to which seed production is currently pollinator-limited or would be improved by bumblebees is a more important unknown. Many factors limit seed production in plants, and there have been few studies investigating pollinator limitation in weedy plants, either in Australia or elsewhere (Hanley and Goulson 2003). However, these few studies indicate that pollinator limitation may indeed be important. A worldwide review found that 62% of 258 species studied experienced pollinator limitation at least some of the time (Burd 1994). In the USA scotch broom, Cytisus scoparius L., which has papilionaceous flowers, suffered significant pollinator limitation of fruit production in all populations and seasons measured, with up to 26-fold increases resulting from hand pollination (Parker 1997). Also in the USA, lack of pollinators limited seed production in the weedy honeysuckle Lonicera japonica Thunb. ex Murray (Larson et al. 2002).

Investigations under the Environmental Impact Study for bumblebees demonstrated that B. terrestris in Tasmania caused a 40% increase in seed set of greater trefoil, Lotus uliginosis Schk, and a 30% increase in tree lupin, Lupinus arboreus Sims, while conversely there was a decrease in seed set in scotch thistle, Onopordum acanthium L. (possibly due to nectar robbing without pollination occurring) (Hergstrom et al. 2002). There is also anecdotal evidence: production of viable seed in rhododendrons, Rhododendron ponticum L., has been increased from 15% to 80% after the introduction of bumblebees (A. Crane, DPIE Tasmania, in Enviroweeds 2004). Rhododendron is a major weed in the western UK (Rotherham 2001) and is becoming weedy in the Blue Mountains in NSW (Heywood Barker 2004).

There is also evidence from horticulturists who argue that bumblebees are required for efficient pollination of certain crops, particularly in the families Fabaceae with trip mechanism flowers and in the Solanaceae where ‘buzz’ pollination is necessary. There are many invasive weedy species in these families present in Australia and by analogy it could be expected that their flowers will also be pollinated more effectively by bumblebees than by honey bees or the (much smaller) native bees. Species which are already major weeds, such as gorse (Ulex europeaus L.), Scotch broom, Spanish broom (Spartium junceum...
cies such as tree lupin, tree lucerne/tagasaste (Cytisus palmensis (H.Christ) Bisby & Nicholls) and Paterson’s curse (Echium plantagineum L.), can be expected to produce more seed and therefore become more costly to manage. There are many other plants such as Desmodium spp, sennas, and others in the families Fabaceae, Boraginaceae and Lamiaceae, which are currently minor weeds but may become much more invasive if their seed production suddenly increases.

**IMPLICATIONS AND ACTION**

*Bombus terrestris* is now widespread in Tasmania, and it will be difficult to prevent its spread into mainland Australia. There is an urgent need for a national management plan, incorporating the detection and eradication of initial populations, similar to that for the cane toad. Deliberate introduction and rearing for horticultural crops should continue to be banned nationwide, as escapes from artificial rearing for greenhouse use are inevitable and will increase spread into new areas and across climatic barriers such as the Nullarbor.

Meanwhile, there is a window of opportunity in which to undertake good scientific studies of the pollination impacts. We need to immediately set up field and experimental studies of seed production in some key invasive weeds, studies designed to investigate the effects of artificial pollination as well as of the current pollinators. These studies should target species with flowers of the type known to be favoured by bumblebees. Studies should be undertaken on some species which are already major weeds (such as broom, gorse, and Paterson’s curse) but also on currently minor species such as tree lupin, tree lucerne/tagasaste (*Chamaecytisus palensis* (H.Christ) Bisby & Nicholls) and plants in the Boraginaceae and Lamiaceae. Tree lupin is pollinated by bumblebees and is increasing in New Zealand. Tree lucerne/tagasaste, native to the Canary Isles where it is presumably also pollinated by *Bombus* species, is widely naturalised in NSW and is already a weed of bushland in south-west Western Australia. We also need detailed studies on seed production in rhododendron where it is becoming weedy in the Blue Mountains. These studies will provide a baseline for comparison, the ‘before’ studies necessary to assess the impact of this invasive species.

Another approach is pre-emptive eradication, already accepted for key ‘sleeper’ weeds (*Cunningham* et al. 2006). For many naturalised plants in the families Fabaceae, Boraginaceae and Lamiaceae and others, the impact of possible improved pollination by bumblebees should now be incorporated into weed risk assessments undertaken to prioritise weeds for eradication, as numerous ‘sleeping giants’ are likely to be awakened by the arrival of the bumblebee.

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