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Commentary

Risks of increased weed problems associated with introduction of non-native bee species

Dave Goulson

Division of Biodiversity and Ecology, School of Biological Sciences, University of Southampton, Bassett Crescent East, Southampton, SO16 7PX, U.K. e-mail: dg3@soton.ac.uk

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Abstract

Bees are widely regarded as beneficial insects. They are major pollinators of many crops and in the case of the honeybee *Apis mellifera* they produce valuable honey. As a result, honeybees originating in Europe and the Middle East have been introduced to almost every country in the world except Antartica. Other species such as various bumblebees and the alfalfa leafcutter bee *Megachile rotundata* have also been widely introduced by man, with little regard to the possible negative consequences. These include: competition with native pollinators for floral resources; competition for nest sites; co-introduction of natural enemies, particularly pathogens, which may infect native organisms; pollination of exotic weeds; disruption of pollination of native plants. Most studies to date have focused on competition, a notoriously difficult process to demonstrate, with equivocal result. Recently, clear evidence has emerged that introduced bees play a major role in pollination of some weed species, and that the associated economic and environmental costs are high. Negative impacts of exotic bees need to be carefully assessed before further introductions are carried out.

Key words: *Apis mellifera*, *Bombus,* bumblebee, competition, honeybee, *Megachile,* pollination, seed set, weeds.

A strong case can be made that exotic species represent the biggest threat to global biodiversity after habitat loss [1, 2]. Yet exotic bees appear to have received disproportionately little attention. Bees are generally perceived to be beneficial, for their role in the pollination of crops and wildflowers and, in the case of the honeybee *Apis mellifera* (L.) (Apidae), for the production of honey. As a result, almost no research was carried out upon the impact of honeybees until the 1980's, by which time they had long since attained a global distribution. Three bee species, the honeybee *A. mellifera*, the bumblebee *Bombus terrestris* (L.) (Apidae) and the alfalfa leaf-cutter bee *Megachile rotundata* (Fabr.) are of particular concern since their range has been considerably expanded due to both deliberate and accidental releases [3]. The possible undesirable effects of exotic bees include: 1) competition with native flower visitors for floral resources or nest sites, 2) spread of parasites or pathogens to native organisms, 3) changes in seed set of native plants (either increases or decreases) and 4) pollination of exotic weeds. There are enormous gaps in our knowledge with regard to whether these processes are actually occurring (reviewed by Goulson [3]). The most convincing evidence of an ecological impact of introduced bees is via pollination of exotic weeds, and this is the focus of this review.

There is abundant evidence that honeybees and bumblebees visit a broad range of flowers, compared to most bee species [4-7]. They appear to prefer to visit exotic flowers [8]. Where they occur, they are usually the most abundant bees present (South Australia [9]; California [10]; Brazil [11]; New Zealand [12]; Israel [13]).

Do visits by exotic bees improve seed set of weeds? In general, rather little is known of the pollination biology of non-native plants, and it is unclear whether inadequate pollination is commonly a limiting factor [14]. By virtue of their abundance and foraging preferences, exotic bees often make up a very large proportion of insect visits to weeds. For example in a site dominated by European weeds in Tasmania, honeybees and bumblebees were the major flower visitors and comprised 98% of all insect visits to the invasive alien weed creeping thistle, *Cirsium arvense* (D. Goulson, unpublished data). In North America, honeybees increase seed set of the yellow star thistle, *Centaurea solstitialis* [15] and are the main pollinators of two important weeds, purple loosestrife, *Lythrum salicaria* [16] and *Raphanus sativus* [17]. Donovan [12] reports that bumblebees are major pollinators of introduced weeds in New Zealand. It thus seems obvious and inevitable that exotic bees will prove to be important pollinators of various weeds [3, 18, 19].

Remarkably, this view has been challenged. It is hard to agree with the conclusions of Butz Huryn and Moller [20] that "Although honey bees may be important pollinators of some weeds, they probably do not contribute substantially to weed problems". Butz Huryn [21] argues that most weeds do not rely on insect pollination, either because they are anemophilous, self-pollinating, apomictic or primarily reproduce vegetatively. This is undoubtedly true of some weed species. For example of the 33 worst environmental weeds in New Zealand [22], nine fall into one of these categories [20]. However, sixteen require pollination and are visited by honeybees, and one is pollinated more or less exclusively by them (the barberry shrub, *Berberis darwinii*). Eight more are listed as having unknown pollination mechanisms [20]. This group includes the tree

lupin, *Lupinus arboreus,* and broom, *Cytisus scoparius*, for both of which the pollination system is well established; they are self-incompatible and rely on pollination by bumblebees [23]. It also includes gorse, *Ulex europeaus,* which is thought to depend on honeybee pollination, and in which seed set is greatly reduced by a lack of pollinators in the Chatham Islands where honeybees and bumblebees are absent [24]. Thus at least four major weeds in New Zealand are pollinated primarily by exotic bees.

L. arboreus is currently a minor weed in Tasmania. However, seed set in areas recently colonised by *B. terrestris* has increased dramatically, and it is likely that *L. arboreus* may become as problematic in Tasmania as it is in New Zealand now that it has an effective pollinator [23]. Its zygomorphic flowers have to be forced apart to expose the stamens and stigma; only a large, powerful bee is able to do this, and no such bees are native to Tasmania. *L. arboreus* is only one of many weeds in Tasmania, New Zealand and southern Australia that originated in the temperate northern hemisphere and are coadapted for pollination by bumblebees.

Lantana camara, a woody shrub originating in south and central America, is among the most widespread and troublesome exotic weeds of the old-world tropics [25-26]. It invades pasture, crops and native ecosystems, causing substantial economic losses and environmental degradation. In Australia alone, *L. camara* is currently estimated to cover approximately 40,000 km^2. Recent studies have shown that *L. camara* requires cross-pollination to set seed, and that honeybees are major pollinators (in some areas the only pollinators) across large tracts of southern Queensland in Australia [27]. Yet honeybee hives are frequently stationed within and adjacent to areas such as National Parks that are threatened by this noxious weed.

Demonstrating that exotic bees increase seed set of weeds is not sufficient in itself to conclusively show that the action of the bees will increase the weed population [21]. No long-term studies of weed population dynamics in relation to the presence or absence of exotic bees have been carried out. Since most weed species are short-lived and dependent on high reproductive rates, it seems probable that seed production is a crucial factor in determining their abundance. Key factor analysis of the life history could reveal whether seed set is directly related to population size.

At present Australia alone has 2,700 exotic weed species and the costs of control and loss of yields due to these weeds costs an estimated AU$3 billion per year [28]. The environmental costs are less easy to quantify but are certainly large. Most of these weed species are at present of trivial importance. The recent arrival of the bumblebee in Tasmania may awake some of these "sleeper" weeds, particularly if they are adapted for bumblebee pollination. Positive feedback between abundance of weeds and abundance of bumblebees is probable, since an increase in weed populations will encourage more bumblebees, and visa-versa. There is currently considerable pressure from horticulturalists to introduce bumblebees to mainland Australia, primarily for glasshouse tomato pollination. If even one new major weed occurs in Australia due to the presence of bumblebees, the economic and environmental costs could be substantial, and may far outweigh the benefits received by tomato growers.

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