Keeping bees in their place: impacts of bees outside their native range

It is well known that introducing non-native organisms can have disastrous consequences, be they cane toads and prickly pear in Australia or grey squirrels and Himalayan balsam in the UK. Many countries now have strict quarantine controls to prevent further introductions. Yet we have something of a blind spot for bees. Because they are widely regarded as beneficial, bees of various species continue to be introduced outside their native range; only rarely and recently have serious objections been raised.

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Of course honey bees *Apis mellifera* have been domesticated for millennia and the transportation of honey bees by man has an ancient history so that their natural range is difficult to define. Nonetheless, they are certainly not native to substantial areas of the globe. Relatively recent events in their artificial range expansion include the introduction of honey bees to North America in about 1620, to Australia in 1826 and to New Zealand in 1839. The African race, *A. m. scutellata* has spread throughout the neotropics and into North America following its introduction to Brazil in 1957. There are now few places on earth where honey bees cannot be found (primarily deserts and the poles).

Honey bees are not the only species to have been transported around the globe by man. Bumble bees (*Bombus* spp.), a group whose natural range is largely confined to the northern hemisphere, have been introduced to various countries to enhance crop pollination. New Zealand now has four established *Bombus* species from the UK. *Bombus terrestris* has become established in Japan, and in 1992 arrived in Tasmania. *Bombus ruderatus* was introduced to Chile in 1982 and by 1994 had spread to Argentina. In addition, various solitary bees have been introduced outside their native range, including *Megachile rotundata, M. apicalis, M. sculpturalis, Osmia cornuta, O. cornifrons, O. coerulescens, O. ribifloris* and *Nomia melanderi*.

What impacts, if any, are these bees having? To a large extent, we have no idea. It is a difficult topic to study. Ideally, one might exclude invading bees from large, replicated areas and compare these sites with those where the invaders are present. But excluding bees is exceedingly difficult. What impacts *might* they be having? There are at least four possibilities:

- Competition with native organisms for floral resources or nest sites.
- Transmission of parasites or pathogens to native organisms.
- Changes in seed set of native plants (either increases or decreases).
- Pollination of exotic weeds.

Most research to date has focused on the first of these, although results have often been inconclusive because of the difficulty in carrying out good experiments (review[3]). However, recent work in California has clearly shown that native bumble bee colonies have lower reproductive success when honey bee hives are nearby.[10]

A range of parasites and pathogens have been accidentally spread around the globe with honey bees, and to a lesser extent with bumble bees, but almost nothing is known as to whether these have spread to native species of bee, and if so what impacts they may have had. It was recently discovered that imports of bumble bees to Japan from Europe has led to the European tracheal mite, *Locustacarus buchneri* being introduced to Japan where it now infects native species.[2]

Efficient pollination requires a match between the morphology of the flower and that of the pollinator. If there is a mismatch, then floral rewards may be gathered without efficient transfer of pollen, a process known as floral parasitism,[7] there is no particular reason why non-native bees should be worse (or better) pollinators of native plants than native bee species, except in those rare instances where plants have tightly coevolved with particular insects. Honey bees are effective pollinators of many plants which they would not have encountered in their natural range, but there is evidence that they can on occasion act as floral parasites, reducing seed set.[5]

There is good evidence that non-native honey bees and bumble bees can increase weed problems. In North America, honey bees increase seed set of the yellow star thistle, *Centaurea solstitialis* [1] and are the main pollinators of two important weeds, purple loosestrife, *Lythrum salicaria* [6] and *Raphanus sativus*.[8] In Australia, honey bees are major pollinators of the invasive weed *Lantana camara*, which has swamped native vegetation and pasture throughout much of Queensland.[4] Each year an estimated Aus$10 million is spent on control of this weed, and the losses to the livestock industry alone are estimated at Aus$7.7 million through decreased stocking densities and deaths of

Figure 1. New Zealand suffers from many serious environmental weeds which exclude native vegetation, such as lupins, *Lupinus* spp. and broom (*Cytisus* spp.), both seen in profusion at this site near Lake Tekapo, South Island. Both are plant species that are pollinated largely by introduced bumblebees.

approximately 1500 cattle per year from *L. camara* poisoning. Despite this honey bee hives are frequently to be found stationed in national parks and cattle ranching areas threatened by this weed. In New Zealand and Tasmania bumble bees are the sole pollinators of the tree lupin, *Lupinus arboreus*, listed as one of the 30 worst environmental weeds in New Zealand, a country that has many serious weeds.[9]

Of course bees do provide enormous benefits to mankind, and it is always going to be difficult to persuade beekeepers that their bees could be doing harm. However, we should not regard bees as universally benign. The precautionary principle argues that we should prevent further deliberate release of exotic bee species (such as of bumble bees in mainland Australia). Unlike many of the other impacts that man has on the environment, introduction of exotic species is usually irreversible. It would also be sensible to avoid placing honey bee hives within environmentally sensitive areas, particularly areas where the native flora is threatened by invasion with honey bee-pollinated weed species.

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Beeswax: quality issues today

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This article concentrates on the main quality issues of Apis mellifera beeswax: production by bees and processing by beekeepers and manufacturers, overall chemical composition, as well as sensory and physicochemical characteristics. The main quality issues today are adulteration and contamination. Contamination from the environment being relatively small, the main contaminants are synthetic and persistent acaricides used in beekeeping. Measures for prevention of contamination are discussed. Information on beeswax economy, as well as on beeswax uses is given.

The Greek philosopher Aristotle believed that beeswax originated in flowers, and this theory predominated until the Renaissance. In 1744 the German scientist Hornbostel[26] reported that bees themselves produce the wax. This report was ignored by the scientific community until Hunter in 1792[28] and Huber in 1814[27] published their work. In 1903 the process of wax synthesis was described in detail by Dreyling.[20]

In this mini-review the main quality issues on beeswax will be discussed, without going into details, which can be found in the cited references.

Wax production in beekeeping

Bees need wax as construction material for their combs. They produce it in their wax glands, which are fully developed in 12- to 18-day-old workers. In older bees the wax glands diminish their activity, however, in emergency situations wax synthesis can be reactivated. The greatest quantities of wax are produced during the growth phase of honey bee colonies, under moderate climate conditions during April to June in temperate climates.

The main raw materials for wax formation are carbohydrates, i.e. the honey sugars fructose, glucose and sucrose.[51] The ratio of sugar to wax can vary from three to 30 : 1, a ratio of around 20 : 1 being typical for central Europe.[51] The stronger the colony, the smaller the ratio, and the more economical the wax production for the colony. One Langstroth frame, containing only 100 g of wax can hold between two and four kg of honey.

THE PERFUME OF BEESWAX

Give me some wax that bees have made
And I will offer you in trade
A candle that is aromatic
Pure, unique and charismatic
by Grant D Morse

Wax production and comb construction activity in the honey bee colony are determined by following factors:

- **Nectar flow:** the greater the flow, the more combs are needed for storage.
- **Brood rearing (egg laying):** the more eggs are laid, the more comb cells are needed.
- **The presence of a queen:** only colonies with a queen build combs.
- **Temperature:** temperatures higher than 15 °C favour comb building activity.
- The presence of pollen as a protein source.

The wax economy of bees seems to function according to the supply and demand principle; there is no unnecessary wax production!

Apis mellifera produce wax in their specialized wax glands, found on the ventral side of the abdomen. A bee has four pairs of glands. The liquid wax is delivered by these glands and cools down immediately to form fine, white wax scales. These scales are taken by the hind legs and processed with the