Better-B practical recommendations

Guidelines for maintaining genetic diversity in European honey bees

The Better-B Consortium | November 2026 | Recommendation n°7

The Better-B project is a four-year Horizon Europe project funded by the European Commission that began in June 2023. The project aims to improve honey bee resilience by restoring balance within the colony and between the colony and its environment. The consortium comprises 16 partners and two associated partners coming from 14 countries. This document is part of a series translating our results into clear recommendations for a diverse target audience. Depending on whether a recommendation is practice-oriented or policy-supporting, it is classified as a "Practical Recommendation" or a "Policy Brief," respectively.

Summary

Honey bees face severe threats from pathogens and climate change. Maintaining genetic diversity in honey bee populations is fundamental to their ability to adapt to these threats. Safeguarding genetic adaptation of honey bees to their local environments is especially important, as locally adapted honey bee strains show increased mortality when moved to new environments to which they are maladapted. Through large-scale genome sequencing as part of the Better-B project, we have uncovered the genetic consequences of extensive human-mediated transport of honey bees over the past century. We also identified signals of both ancient and recent natural selection, pointing to molecular mechanisms underlying local adaptation. In addition, we analysed genetic variation in populations experiencing ongoing natural selection for *Varroa* resistance, finding that these populations do not show reduced genetic variation.

The problem

Genetic diversity is recognised as a key component of population vitality and viability. It provides raw material for a species to evolve and adapt to a changing environment. Low genetic variation can reflect inbreeding, which results in the expression of harmful mutations, reducing population fitness. An important component of genetic variation is local adaptation, whereby natural selection favours specific genotypes in specific environments. Disrupting these associations between genotype and environment can have negative effects on survival. It is therefore crucial to safeguard genetic variation and preserve locally adapted genotypes, to enable honey bees to adapt and evolve to new threats. These threats are both biotic (*Varroa*, pathogens, invasive species) and abiotic (climate change, extreme weather events).

A significant problem is that many beekeeping practices adopted during the last century have negative impacts on genetic diversity. Honey bees are native to Europe, where populations historically developed distinct, genetically structured groups that are adapted to their local environmental conditions. Over the last century, widespread trade—particularly importing bees from Southeastern Europe into Northern Europe—significantly altered the genetic composition of northern populations. Large-scale queen breeding, and importation of these queens from a limited number of breeding lines, replaces local honey bee populations with more genetically homogeneous ones that are not locally adapted. Furthermore, chemical treatment of honey bee colonies against *Varroa* weakens the forces of natural selection and prevents the development of varroa resistance. There is also concern that strong selection by *Varroa* may reduce genetic variation due to population bottlenecks.

The evidence

Within Better-B, genome sequencing was used to characterize the genetic ancestry of European honey bee populations, investigate the genetic basis of local adaptation and assess how survival under high *Varroa* pressure affects genetic variation. Our results lead to recommendations for maintaining genetic diversity and locally adapted populations of European honey bees.

1. European population structure reflects heavy importation

Our analysis of over 1000 genomes from all over Europe has revealed the genetic consequences of extensive human-mediated movement of honey bees over the past century. Honey bees in Northern European now derive most of their ancestry from southern stock, though a degree of northern ancestry still persists. This reflects the popularity of honey bees from Southeast Europe (mainly Italy and Slovenia) in beekeeping that led to their mass importation to Central, Northern and Western Europe.

We find that genetic diversity is highest in populations of mixed ancestry, which could reflect high adaptive potential. However, in some regions of Central, Northern and Western Europe there is little of the original ancestry remaining, which could limit local adaptation. Mass importation can therefore threaten local adaptations and reduce overall genetic resilience.

2. Distinct signals of ancient and ongoing selection

We identify signals of selection acting on subspecies level, indicating that honey bee subspecies have specific ancient adaptations tied to their ancestral environments. In addition, we uncover evidence of ongoing natural selection in present day hybrid populations, actively shaping these hybrid populations to their local conditions. This is consistent with the COLOSS genotype–environment experiment [1], in which local colonies generally survived longer than colonies introduced from other regions. These findings support the conservation and breeding of locally adapted honey bee populations.

3. *Varroa* surviving populations can retain genetic diversity

Several European honey bee populations have survived for many years without *Varroa* treatment. These populations could pave the way for the evolution of *Varroa* resistance in honey bees in Europe more generally. However, these populations can experience severe bottlenecks due to substantial mortality caused by *Varroa*, and lose their genetic diversity and resilience. However, genome sequencing showed that the studied *Varroa*-surviving populations have similar genetic diversity to nearby managed ones. This suggests that strong selection by *Varroa* does not necessarily cause a major loss of overall diversity.

Practical recommendations

1. Limit large-scale queen breeding and importation

Commercial queen rearing and distribution reliant on a limited number of genetic lines is detrimental to genetic diversity. Furthermore, the traits encouraged by commercial breeders, while beneficial for honey production, may have adverse effects on resilience. We recommend beekeepers and breeding organizations to work with local, diverse stocks, and avoid excessive reliance on a limited number of commercial lines, to maintain resilience and foster ongoing adaptation.

2. Support programmes to preserve ancestral bee subspecies

Conservation organizations and local breeding groups, play a vital role in protecting native honey bee lineages and preserving genetic diversity in regions that experience extensive importation. In Europe, this applies primarily to the dark bee *Apis mellifera mellifera*, native of Central, Northern and Western Europe. In some countries such as Germany this native bee has been effectively lost whereas in others, populations are maintained by local breeding societies. We recommend that these societies are supported and provided with areas where importation of honey bees is restricted to preserve this genetic ancestry. Information about conservation of the dark bee can be found at the International Association of the European Dark Honey Bee https://www.sicamm.org.

3. Establish *Varroa*-treatment-free populations of locally adapted bees in multiple locations

Varroa-surviving populations have been established in multiple locations in Europe and these populations have high levels of genetic variation. However, the enhanced survival of these honey bees is often lost when they are moved to other geographic locations, suggesting that local adaptation is an important factor in their resilience. We therefore recommend establishment and maintenance of *Varroa*-surviving populations in multiple locations in Europe with diverse climatic conditions to foster Varroa resilience in locally adapted populations. This recommendation is compatible with the two-track management approach presented in recommendation 1 and the DBB protocol in recommendation 8.

Path to implementation - Examples - Impact

To translate these genomic findings into concrete management practices, action is required across multiple levels of the beekeeping sector:

Beekeepers and local associations should shift to local queen rearing. Transition from purchasing imported mated queens to rearing queens locally from a broad and genetically diverse group of colonies that perform well and overwinter successfully under local conditions. Give preference to colonies showing good hygienic behaviour and low *Varroa* mite loads.

Policymakers and environmental agencies should support the maintenance of honey bee conservation areas. Develop a common European framework that allows national and regional authorities to designated conservation and controlled matting areas (e.g., islands or isolated valleys) where the importation of non-native honey bee strains is restricted. On top of it incentivize sustainable breeding by supporting research and advisory networks, and provide funding for beekeepers participating in long-term, non-chemical Varroa resistance and conservation programs.

Examples

Varroa-surviving populations through natural selection - such as those on the island of Gotland (Sweden), the Avignon population (France), and naturally surviving wild/feral populations in the UK and Netherlands - demonstrate that European honey bees can evolve stable, long-term resistance to Varroa destructor while preserving high overall genomic diversity.

Several native subspecies conservation initiatives like the protection of *Apis mellifera mellifera* on the island of Læsö (Denmark), networks in Ireland, Sweden and Norway, and local breeding societies across Western and Central Europe show how dedicated mating sanctuaries effectively preserve ancestral genetic lineages.

Impact

Enhanced colony resilience & survival: Prioritizing locally adapted stock and natural selection reduces seasonal colony losses caused by harsh winter conditions, local microclimatic extremes, and emerging pathogens.

Reduced chemical dependency: Fostering naturally Varroa-resistant populations decreases the reliance on synthetic acaricides, lowering management costs for beekeepers, reducing labour, and preventing chemical residue buildup in wax and honey.

Preservation of evolutionary potential: Safeguarding local adaptations and preventing the eradication of native ancestral subspecies ensures that European honey bee populations retain the broad genetic diversity needed to adapt to future challenges posed by climate change and invasive species.

Further reading

Büchler R, Costa C, Hatjina F, Andonov S, Meixner MD, Conte YL, et al. The influence of genetic origin and its interaction with environmental effects on the survival of Apis mellifera L. colonies in Europe. Journal of Apicultural Research. 2014;53: 205–214. doi:10.3896/IBRA.1.53.2.03

Webster M, Taliadoros D, Pinto MA (2026). Better-B Deliverable 3.1: Adaptive Loci

Webster M, Kotrschal S, Taliadoros D (2006). Better-B Deliverable 4.1: Genetics of Darwinian Colonies

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This work was supported by the Better-B project, which has received funding from the European Union, the Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee (grant number 10068544).

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