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OPINION
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Pitting Wild Bees Against Managed Honey Bees in Their Native Range, a Losing Strategy for the Conservation of Honey Bee Biodiversity

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Significant losses of managed honey bee colonies (*Apis mellifera* L.) have been reported annually around the world (Neumann and Carreck, 2010; Potts et al., 2010). It is also well-established that wild bees face localized and broad-scale threats as a result of human activities, including land-use intensification (pesticide use and lack of food resources) and the spread of invasive species and diseases (Potts et al., 2016). Consequently, in recent decades, the species richness of most groups of pollinating bees has declined across Europe and North America (Biesmeijer et al., 2006; Cameron et al., 2011; Burkle et al., 2013; Ollerton et al., 2014).

However, managed honey bees themselves may exacerbate these pressures on wild bee populations, thereby decreasing wild bee abundance and diversity (Russo, 2016; Geslin et al., 2017). For instance, increased densities of managed honey bees in their native and non-native ranges could affect wild bees via resource competition and changes in plant communities (see for a review Mallinger et al., 2017, or disease transmission Fürst et al., 2014; Vanbergen et al., 2018). Indeed, despite some inconsistency of effects, studies mostly reported negative influences of managed honeybees on wild bees (Mallinger et al., 2017). Moreover, honey bees (whether managed or wild) could pose broader risks to non-native ecosystems (e.g., North and South America, Eastern Asia and Australia) by interfering with local pollinators for the pollination of local flora, increasing seed sets of exotic weeds, and competing with other organisms (e.g., bees, birds, mammals) for nesting cavities (Goulson, 2003; Russo, 2016; Ollerton, 2017). Finally, another consequence of the spread of the European honey bee around the world is the progressive replacement of beekeeping with native bees [e.g., *A. cerana* F. in Asia (Theisen-Jones and Bienefeld, 2016) and stingless bees in Mexico (Quezada-Euán, 2018)] by *A. mellifera* L., which is more productive but might threaten local biodiversity.

As a consequence, the pressure of managed honey bees on wild bees has led to a growing debate between the need for the conservation of native and wild bees and the use of managed honey bees in natural and protected areas (Geldmann and González-Varo, 2018; González-Varo and Geldmann, 2018; Kleijn et al., 2018; Saunders et al., 2018).

It was notably advised that managed honey bees should not be placed in protected areas, but only in agricultural areas, to conserve and avoid damage to wild pollinators (Colla and MacIvor, 2017; Geldmann and González-Varo, 2018). This claim was first made without discriminating the native and non-native ranges of managed honey bees (Geldmann and González-Varo, 2018) and later, the authors advocated that within their native range, a limited number of honey bee hives could be placed in protected areas (González-Varo and Geldmann, 2018). While we agree that extensive use of managed honey bees may be problematic for wildlife conservation and we should control the number of hives in native, protected areas, we believe that, contrary

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to the situation in non-native regions, pitting wild bees against managed honey bees in their native range is counterproductive with regards to the conservation of honey bee biodiversity. Indeed, the western honey bee *Apis mellifera* L. is also a component of biodiversity in its native range (Africa, Europe, Western, and Central Asia), where it has adapted to diverse environmental conditions and natural habitats (De la Rua et al., 2009). The conservation of honey bee biodiversity would therefore benefit from the maintenance of small-scale beekeeping management and conservation areas in natural and protected lands.

HONEY BEE BIODIVERSITY IN ITS NATIVE RANGE

Despite a long-standing exploitation of honey bees by humans, which dates back nearly 9,000 years (Roffet-Salque et al., 2015), endemic subspecies-specific phenotypes and genetic footprints can still be identified in the honey bee native range (De la Rua et al., 2009; De la Rúa et al., 2013; Meixner et al., 2010). In addition, the number of subspecies, originally estimated at 26 (10 in Europe), has recently increased with the description of two new subspecies in Africa [*A. m. simensis,* (Meixner et al., 2011)], and Asia [*A. m. sinisxinyuan,* (Chen et al., 2016)]. The presence of previously unidentified subspecies would also suggest that the actual native range of *A. mellifera* is not completely defined. Indeed, the discovery of *A. m. pomonella* in 2003 further extended the endemic range of *A. mellifera* by about 2,000 km eastward (Sheppard and Meixner, 2003).

This natural diversity of honey bee populations (each generally composed of both managed and feral colonies) reflects a large range of local and regional adaptations to various ecological conditions. Indeed, subspecies, which have been estimated to diverge 0.7–1.3 million years ago (Garnery et al., 1992; Arias and Sheppard, 1996), and ecotypes have developed behavioral and phenological adaptations to local environments, characterized by specific climatic conditions and patterns of resource availability (Ruttner, 1988; De la Rua et al., 2009). For instance, the Landes ecotype of *A. m. mellifera* (southwest France), described in managed honey bee populations, has tightly linked its annual brood cycle to the local floral phenology of ling heather (*Calluna vulgaris* L.) (Louveaux et al., 1966). This ecotype is quite persistent, because 40 years later, half of the local managed colonies (Landes) that were tested were found to have a brood cycle similar to the one described in 1966 (Strange et al., 2007). Another example is the climate-driven separation of the two subspecies *A. m. carnica* and *A. m. macedonica* at an average threshold temperature of 9°C (Coroian et al., 2014): *A. m. carnica* being more abundant in areas with an average temperature below 9°C and inversely for *A. m. macedonica*.

GENETIC CONSERVATION OF HONEY BEES IN THEIR NATIVE RANGE

The conservation of these honey bee populations (feral and managed colonies) is a pressing priority, given that their survival in natural habitats is endangered by the same factors that affect wild pollinators (De la Rua et al., 2009; Jaffé et al., 2010; Meixner et al., 2010; Goulson et al., 2015). Furthermore, endemic populations are highly adapted to their local environment through a range of unique behavioral and morphological traits, such that removal from their native range is associated with lower survival and productivity (Buchler et al., 2014). For instance, some managed populations have been found to naturally survive *Varroa* mite infestation, a major pest of honey bee colonies (Locke, 2016). However, when removed from their native environment, these populations became as sensitive to *Varroa* as non-resistant local populations, suggesting that the mechanism of mite resistance is dependent on genotype-environment interactions (Buchler et al., 2014; Meixner et al., 2014, 2015). Therefore, the diversity of honey bee populations constitutes a great natural heritage that needs to be preserved, notably for preventing colony losses. This is further supported by the European regulation on organic beekeeping, which recommends "the use of European breeds of *Apis mellifera* L. and local genotypes" (Council Regulation ECN°889/2008)[1].

For that purpose, we concur that beekeeping in protected areas should be done in a way that is not detrimental to wildlife (e.g., restricted number of colonies). While it is not yet known what would constitute a safe level of managed honey bee colonies, small-scale beekeeping management could be a win-win situation for both the conservation of wild bees and honey bee biodiversity. The number of managed honey bee colonies in protected areas needs to be small enough that it would limit the impact of resource competition and disease transmission to wild bees but still allow the implementation of conservation areas for managed honey bee colonies. These conservations areas managed by technical institutes or beekeeper associations (non-profit organization) would then facilitate the development of conservation genetics programs. For instance, four conservation areas have been created in nature reserves of Switzerland for preserving the local honey bee subspecies *A. m. mellifera* (Parejo et al., 2016). Downsizing beekeeping management of local honey bees in such conservation areas would also reduce potential disease transmission and protect feral colonies in the vicinity. Feral colonies, which represent a reservoir of genetic diversity (Oleksa et al., 2013), can be important for the maintenance of endemic populations by beekeepers and conservation programs (management of wild-caught swarms). However, the use or protection of feral colonies should be considered as a complementary management measure to conserve honey bee genetic diversity rather than an exclusive solution since their nests are hard to detect, and therefore their number, densities, survival, and genetic background are very difficult to assess (Jaffé et al., 2010; Kohl and Rutschmann, 2018) as compared to managed honey bee colonies.

[1]Commission Regulation (EC) (2008). *Laying Down Detailed Rules for the Implementation of Council Regulation (EC) No 834/2007 on Organic Production and Labeling of Organic Products With Regard to Organic Production, Labeling and Control. No 889/2008.*

As for the extreme scenario in which managed honey bees should be limited to agricultural areas, beekeepers would need to intensify their practices to compensate for colony losses due to resource scarcity and pollution, resulting in revenue loss due to the low price of honey from mass-flowering crops. As a result, intensive beekeeping would threaten the extinction of local honey bee populations by favoring the expansion of only the most productive (high honey yields) and adaptive subspecies or ecotypes that thrive in agricultural areas. The use of non-local honey bees would also reinforce the development of admixed populations, which may have a higher genetic diversity (Harpur et al., 2012) but which would contribute to the loss of important naturally–selected traits (De la Rúa et al., 2013). This would be counterproductive given that the current challenge of livestock production is to limit overbreeding and the loss of valuable local adaptations in order to adapt to rapidly changing environments (e.g., climate change, spread of new diseases) (Notter, 1999).

Finally, preserving the management of endemic honey bee subspecies in their natural habitats would not only benefit the conservation of honey bee biodiversity but would also help to adapt beekeeping activity and crop pollination to climate change (Le Conte and Navajas, 2008). Indeed, maintaining a reservoir of adaptive traits to different climatic regions in the native ecosystem will be extremely useful for selecting honey bee populations that are best suited for providing pollination services of crops under new climatic conditions, whether it is in their native or non-native range.

CONCLUSION

We do not dispute that a high density of managed honey bees may introduce resource competition with wild pollinators and favor the spread of diseases. Indeed, it seems unavoidable to prevent (non-native range) or limit (native range) the access of managed honey bees to areas where wild pollinator species are threatened (Henry and Rodet, 2018). However, in the current context of a fast-evolving biodiversity crisis at global and local scales, there is a need for implementing adequate policies to protect native and locally adapted honey bees since they provide an important reservoir of adaptation for beekeeping activity and crop pollination services. For that purpose, rather than creating opposition between managed honey bees and wild pollinators, and creating conflicts between stakeholders, we need to find ways to reconcile wild pollinator conservation with responsible and sustainable beekeeping practices in natural and/or protected areas of the honey bee native range (e.g., conservation areas for local honey bees). Therefore, before considering any exclusion of managed honey bees from their native and natural habitats, we should start with conservation policies that place priority on the restoration of native habitats to support all bees, managed and wild.

AUTHOR CONTRIBUTIONS

CA and AD conceived and wrote the paper. YLC provided new ideas and participated in writing.

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