Pollination: threats and opportunities in European beekeeping

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Introduction

Pollination is crucial for both crop production and the conservation of wild flowering plants. The honeybee (*Apis mellifera*) is a ubiquitous pollinator and is the dominant pollinator to more than half animal-pollinated crops (Klein et al. 2007), even though wild pollinators are essential to provide optimal pollination services in many crops, not to mention natural vegetation (Garibaldi et al. 2013). However, there is a global decline of insect pollinators across Europe (Potts et al. 2010; Breeze et al. 2014) and the USA (NRC 2007) and a worldwide decline of honeybees, known as Colony Collapse Disorder (CDD) (Oldroyd 2007). In this paper we outline some key elements of this worrying situation and offer some avenues for hope if beekeeping is to be maintained.

Honeybees as fundamental elements of services of pollination and food production

Out of the fifteen ecosystem services identified by the Millenium Ecosystem Assesment (2005), pollination is described as one of the most important (Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services, IPBES 2016). Animal (mainly insect) pollination is crucial for many cultivated crops, and is known to significantly increase the productivity of 85% of 264 crops cultivated in Europe (Williams, 1994) and for about 70% of 87 main crops cultivated worldwide (Klein et al. 2007). Over the last five decades, global agriculture has become increasingly pollinator-dependent, with an increase by a factor of 3 in the number of crops requiring the intervention of pollinators (Aizen & Harder 2009). Spatial analyses demonstrate that approximately 10% of the worldwide agricultural surface is pollinator dependent (Gallai et al. 2009), but this dependency is far from uniform across the globe (Lautenbach et al. 2012) and may reach as much as 30% in several agricultural hotspots. The global value of insect pollination, in which honeybees play a prominent role, has been estimated at around 150 billion euros (Gallai et al. 2009). Moreover, agricultural and biofuel policies from the European Union have encouraged the substantial growth of insect-pollinated crops throughout Europe.

Beekeeping is linked to the production of honey and, to a lesser degree, wax, propolis, royal jelly, pollen and venom. While bee products are used mainly as foods, which are recognized as incredibly high sources of micro-nutrients (vitamins, iron, mineral elements, etc.) their contribution to human health – especially in developing countries – should not be overlooked (Chaplin-Kramer et al. 2014): they intervene in countless therapeutic practices and traditional healing systems, and are therefore of paramount value for the wellbeing of the citizens in low- and medium-income countries (Chaplin-Kramer et al. 2014; IPBES (chap. 5 2016). However, at the same time, the global decline of wild pollinators is now evident (Goulson et al. 2008) and parallel declines of insect-pollinated plants have been observed locally (Biesmeijer et al. 2006).

Similarly, a decline in managed honeybees and beekeepers has also been demonstrated in recent decades in Europe (Potts et al. 2010) and in the USA (NRC 2007). Breeze et al. (2014) demonstrate that the recommended number of honeybees required to provide crop pollination across 41 European countries has risen 4.9 times faster than honeybee stocks between 2005 and 2010. In 22 out of the 41 countries studied, 90% of the demand for honeybee stocks is not met. Unsustainable practices have been regularly denounced, as in the USA, which has developed the largest pollination exploitation industry: more than two million honeybee colonies are proposed for rent in order to pollinate vast monocrop fields and plantations (Morse & Calderone 2000).

The use of honeybees as a unique pollinator species is a particularly risky strategy, given that at least half of the rented hives have to be transported over

long distances across the country to California to ensure the pollination of almond (*Prunus dulcis*) orchards for a period of six weeks (Sumner & Boriss 2006). An irreversible situation of 'no pollination's land' is already reached in a growing number of Asian countries, where local plantation workers are obliged to pollinate the trees, for instance apple trees, by hand, replacing the absent natural pollinators; a situation caused both by a drop of native wild pollinators and the unavailability of honeybees for this pollination service (Partap & Partap 2007).

Taken altogether, these studies alert us to the significant threat of the enhanced vulnerability of worldwide food production induced by the decline of (wild and managed) insect pollinators (IPBES 2016). The resilience of this food production system relies heavily on the capacity of many countries to cope with major losses of wild pollinators. Such a dramatic situation also highlights the numerous critical gaps in our current understanding of pollination service supply and demand, and highlights the pressing need to invest in further research into this issue (Breeze et al. 2014). If we are to make actionable policy out of these general concerns, we must identify the areas that are most vulnerable to the ongoing decline in pollination services and investigate the many ramifications resulting in a deterioration of human wellbeing (Chaplin-Kramer et al. 2014; IPBES 2016). Cooperation between sustainable agriculture and beekeeping as well as a clearer understanding of pollination service supplies and demands on different scales offer some pathways toward a more resilient pollination-dependent crop system.

Towards the homogenization of beekeeping practices and use of several honeybee landraces

Up to the beginning of the 20th century, beekeeping was essentially guided by traditional practices along with the use of local honeybee landraces. These landraces were adapted to the constraints of the local environment and had generally lasted for several centuries.

Through constant observation of bee activities and behaviors, traditional beekeepers have developed empirical and sophisticated knowledge about their bees and the related bee products (Dounias & Michon 2013). They have gained extensive understanding of local climate variability and fluctuations as part of their traditional ecological knowledge that are acquired and transmitted through generations (Berkes et al. 2000).

However, most of the local knowledge sustaining local beekeeping practices have been drastically weakened by global change together with the bee strains

with which they had evolved. Since World War II, human activities have increasingly impaired the planet's ecosystems, but at different amplitudes depending on the regions, and with a noticeable contrast between developing and developed countries (IPBES 2016). Consequently, beekeeping is characterized by a wide range of practices, from the gathering of wild honey in natural colonies to the industrial exploitation of domesticated honeybees. In between these two extremes, a vivid continuum of domestication provides a broad variety of traditional forms of beekeeping that are grounded in the specificities of local socio-ecological features (Crane, 1999). In Europe, the modernization of agriculture over the past century has induced profound changes in land-use systems and landscape fragmentation but also an exponential increase in the use of pesticides and insecticides. Beekeeping has also been deeply transformed, notably via the spread of movable frame hives, which enable the beekeepers to harvest honey without destructively cutting out the wax combs (Crane, 1999). However, because the beekeeping of the single domesticated honeybee initially appears homogenous throughout Europe, understanding of how this activity has evolved at a very local level is generally overlooked (Lehébel-Péron et al. 2016). Such an understanding is nonetheless crucial if appropriate community-based resource management is to be developed in socio-ecological systems that have been profoundly shaped by beekeeping activities.

Photo 1
Log hives used in traditional beekeeping in the Cevennes region.
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To illustrate this necessity, a recent study was carried out focusing on the ethnoecological history of local knowledge regarding beekeeping in the Cévennes National Park (southern France). The goal was to trace back the major episodes of local beekeeping, by considering the modifications of chosen beehive models

and bee landraces, as well as the valorization of beehive products in tune with evolving social and economic circumstances (Lehébel-Péron et al. 2016). This study revealed a number of salient features, such as the first evidence of the use of log hives in the early 17th century – they were time-stamped and retrospectively set into context. Artisanal beekeeping of the local black bee hosted in log hives persisted until the 1970s, which saw a transition to modern beekeeping using frame hives, selected bee landraces, and the professionalization of the local honey trade sector. Beekeepers from the Cévennes region only later progressed from a domestic and landscaped beekeeping – which was optimized for the context of self-sufficient and multi-activity lifestyle – into windfall beekeeping driven by the search for maximized honey yields and supported by a diversification and a hybridization of bee landraces.

Such combined historical and biocultural perspectives of beekeeping in Cévennes should serve to suggest reasonable outcomes for conservation and help reconcile the preservation of a patrimonial and traditional beekeeping with the enhancement of a still emerging local honeybee market. This example demonstrates that the shift in beekeeping processes has somehow reinforced the resilience of a traditional Cévennes way of living, even if the risk of a loss in local knowledge remains acute.

In Corsica, almost all of the traditional beehives have been destroyed and the local knowledge of traditional beekeeping has virtually disappeared. This extinction is the consequence of the Protected Designation of Origin (PDO) linked to the use of modern hives and the development of a new and labeled honey production. The norms established at the European Union take insufficient account of local knowledge and know-how.

In addition, these major and fairly recent changes in beekeeping practices were also marked by the use of novel landraces of honeybees. The introduction of non-native landraces as well as the displacement of hives (transhumance) to flowering sites that are normally exploited by local and rustic landraces has become customary in the attempt to optimize honey production and cope with the colony losses after the critical winter period (Breeze et al. 2014; IPBES 2016). In several countries of the Mediterranean area, beekeepers currently use several landraces of honeybees. Exotic sub-species, such as the Italian (*A. m. ligustica*) and the Caucasian (*A. m. carnica*) bees or even hybrid landraces like the Buckfast, are chosen according to their reduced aggressiveness and their higher honey productivity (Ruttner, 1988; Crane, 1999; Wallberg et al. 2014). This is what happened in Cévennes, but not in Corsica, where the island factor fostered the persistence of the local honeybee. Favored by the yearly renewal of queens, the spontaneous hybridization of landraces among the hives constitutes an acute problem of modern beekeeping in most Mediterranean and European countries. Genomic analyses indicate that managed honeybees are suffering from a reduction in genetic diversity, not only in Europe with its several native landraces (Wallberg et al. 2014), but also in North America where domesticated bees have been introduced (Harpur et al. 2012).

The changing world of honeybees, beekeeping and beekeepers

As described above, the paradoxical trends observed at the globe scale between the marked depletion of pollinators and their increasing solicitation for pollination services has led to an unsustainable – if not irreversible – situation. The urgent need to respond to this dramatic threat has only recently been expressed (Breeze et al. 2014; IPBES 2016). Nevertheless, worldwide honey production is dominated by a professional beekeeping sector that must be responsive to the dictates of the market and that is apparently puzzled by global change.

However, wild honey harvesters and traditional beekeepers – mainly composed of local communities and amateur honey producers – could play a prominent role in monitoring the incidence of global change on local biodiversity, through their daily and thorough observations of bees, especially in places where this incidence is insufficiently assessed by the scientific community (Dounias 2009). This local ecological knowledge would help leverage the resilience of communities forced to adjust their livelihoods to the multiple stressors of global environmental change (Gómez-Baggethun et al. 2013; Roué et al. 2015).

Traditional ecological knowledge and local perceptions are being increasingly solicited to reduce knowledge gaps for conservation and mobilized to achieve more effective ecosystem-based management (Berkes et al. 2000). Another study, also in the Cévennes National Park (southern France) exploring the production of heather honey, explored whether combining scientific and traditional knowledge is a promising means to elaborate alternative ways of adapting to ongoing changes that are compatible with local values and priorities (Lehébel-Péron et al. 2015).

The production of this very particular type of honey, which was formerly massively exported to Germany, has dramatically dropped over the last two decades. The study showed that the local drivers of this decline are the result of a combination of factors from the environmental (climate change, landscape closure, pollution, sanitary problems with bees, notably varroa parasitism) to the economic (emergence of competitive markets) and the social (change in practice of agricultural practices). The study also pointed out that the scientific state of knowledge is highly congruent with the perceptions expressed by local beekeepers and the few experts of the heather honey sector. Taken together, the views jointly expressed by the three categories of knowledge and expertise significantly enhance the accuracy of our understanding of the drivers of change affecting heather honey production, much more than when they are taken separately. Once again, local socioecological resilience could be enhanced by the development of a local market that would gain from branding a new ‘Made in Cévennes’ honey production. This could be a promising way to promote an artisanal yet cost-effective activity that would benefit from the specific biocultural features of the National Park and successfully meet both conservational and development goals.

Perspectives for pollination by honeybees and beekeeping

Given the urgent need to tackle the incommensurable threat of the pollination paradox, solutions are surely to be found in a complex transition toward a truly sustainable agriculture and meaningful cooperation between agriculture and beekeeping, but also in a better match between supply and demand. However, the large variety of beekeeping practices and the diversity of ecological and socioeconomic situations between developing and developed countries necessitate the adoption of joint strategies at the very local level. If professional beekeepers were to develop more sustainable practices, local beekeepers and honey gatherers would have to adjust their adaptive responses to change in ways that do not impair the integrity of their livelihoods.

Supporting the varied local production of native honeybees while encouraging more eco-aware practices, along with advocating for the labeling of knowledge-based singular productions while reinforcing the dialogue between experts of different types of knowledge and know-how: these are certainly the key challenges to address in the near future. But acknowledging the expertise of traditional beekeepers and honey hunters is an absolute prerequisite in order to obtain their prior informed consent and ensure their voluntary adherence to any community-based management initiative.

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The Mediterranean Region under Climate Change

A Scientific Update

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