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GLOBAL HONEY BEE COLONY DISORDERS AND OTHER THREATS TO INSECT POLLINATORS

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Adult honey bee with a brown varroa mite riding on the thorax. Photo courtesy of Stephen Ausmus. USDA-ARS, United States, License: public domain

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Worker honey bee pollinating an almond flower in California. Photo courtesy of J. Pettis USDA-ARS, United States.

Introduction

Current evidence demonstrates that a sixth major extinction of biological diversity event is underway[1]. The Earth is losing between one and ten percent of biodiversity per decade[2], mostly due to habitat loss, pest invasion, pollution, over-harvesting and disease[3]. Certain natural ecosystem services are vital for human societies.

Many fruit, nut, vegetable, legume, and seed crops depend on pollination. Pollination services are provided both by wild, free-living organisms (mainly bees, but also to name a few many butterflies, moths and flies), and by commercially managed bee species. Bees are the predominant and most economically important group of pollinators in most geographical regions.

The Food and Agriculture Organisation of the United Nations (FAO)[4] estimates that out of some 100 crop species which provide 90% of food worldwide, 71 of these are bee-pollinated. In Europe alone, 84% of the 264 crop species are animal-pollinated and 4 000 vegetable varieties exist thanks to pollination by bees[5]. The production value of one tonne of pollinator-dependent crop is approximately five times higher than one of those crop categories that do not depend on insects[6].

Has a "pollinator crisis" really been occurring during recent decades, or are these concerns just another sign of global biodiversity decline? Several studies have highlighted different factors leading to the pollinators' decline that have been observed around the world. This bulletin considers the latest scientific findings and analyses possible answers to this question. As the bee group is the most important pollinator worldwide, this bulletin focuses on the instability of wild and managed bee populations, the driving forces, potential mitigating measures and recommendations.

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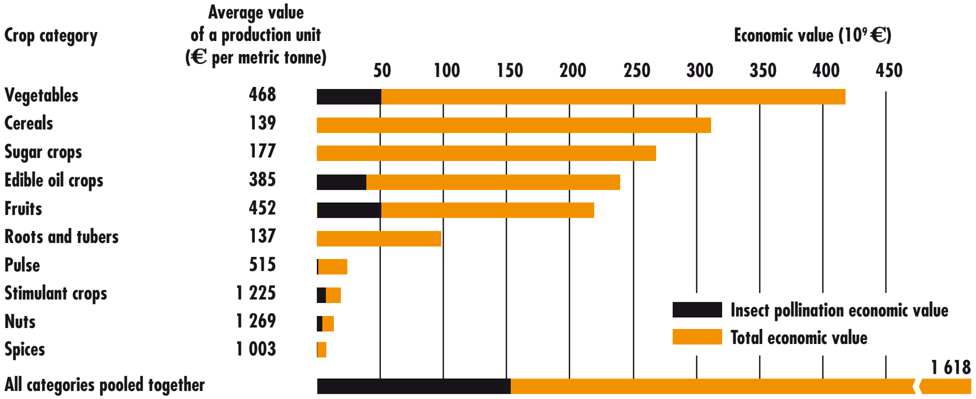
1 UNEP 2006, "Global Environment Outlook: environment for development (GEO-4)". Box 5.3, p.162.
2 Wilson E.O, 1999. "The Diversity of Life" (new edition). W.W. Norton & Company, Inc. New-York.
3 Wilcove D.S, Rothstein J, Dubow A, Phillips and Losos E. 1998. "Quantifying threats to imperiled species in the United States". BioScience, 48: 607-615
4 Food and Agriculture Organisation of the U.N. at www.fao.org/ag/magazine/0512sp1.htm
5 Williams I.H., 1996. "Aspects of bee diversity and crop pollination in the European Union". In The Conservation of Bees (Metheson, A. et al., eds), pp. 63–80, Academic Press.
6 Gallai N. et al., 2009. "Economic valuation of the vulnerability of world agriculture confronted with pollinator decline". Ecological Economics, 68: 810-821

1. Pollination and pollinators

Pollination is the transfer of pollen from a flower's male organs to a flower's female organs. This process is critical to fruit and seed production and is usually provided by insects and other animals searching for nectar, pollen or other floral benefits. Pollination is vital to our ecosystems and to human societies. The health and well-being of pollinating insects are crucial to life, be it in sustaining natural habitats or contributing to local and global economies (Figure1).

Figure 1: Economic impact of insect pollination on agricultural production used directly for human food worldwide



The contribution of pollinators to the production of crops used directly for human food has been estimated at €153 billion globally, which is about 9.5% of the total value of human food production worldwide [6].

Animal-mediated pollination boosts the reproduction of wild plants on which other services or service-providing organisms depend. Some commercial plants, such as almonds or blueberries, do not produce any fruit without pollinators. For many, a well-pollinated flower will contain more seeds, with an enhanced capacity to germinate, leading to bigger and better-shaped fruit. Improved pollination can also reduce the time between flowering and fruit set, reducing the risk of exposing fruit to pests, disease, bad weather, agro-chemicals and saving on water.

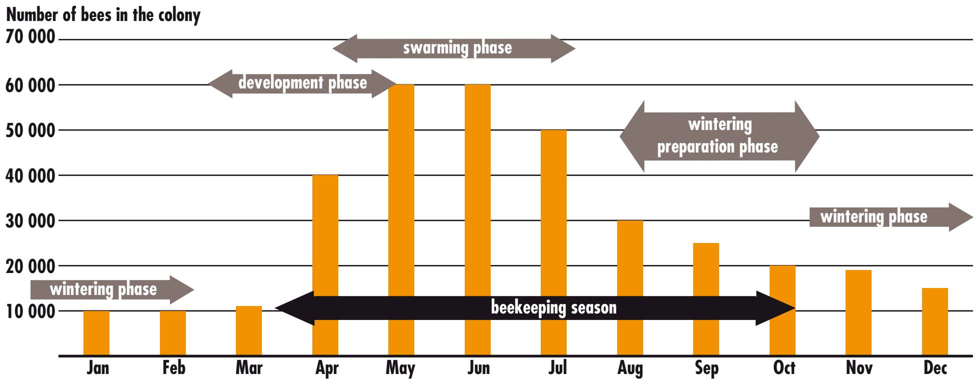
Mutually beneficial relationships have developed over time between pollinator anatomy and plant flower structures – as well as mechanisms that plants use to attract reproductive assistants in exchange for food rewards. These co-adaptations can be so specialized that the loss of one species threatens the existence of another. This raises troubling questions about the potential consequences of declining diversity in pollination networks[7] – an ecosystem service that is often cited as endangered in scientific literature.

2. Variation in managed pollinator populations

Among the 20 000 known bee species worldwide, the most common domesticated bees are honey bees, *Apis mellifera*. Native to Europe, Asia and Africa, their value ranges from honey production, wax, propolis and royal jelly, to the efficient pollination of crops. Honey bees remain the most economically valuable pollinators for crop monocultures worldwide. Yields of certain fruit, seed and nut crops decrease by more than 90% without these highly efficient pollinators[8].

It is problematic to estimate the global economic value of the pollination services provided by managed species, as it is difficult to know if crops have been pollinated by managed or wild individuals. Nevertheless, recent estimates range between €22.8 to 57 billion[9], including apiculture markets and particularly all cash-crop yields.

Figure 2: Mean theoretical honey bee population per hive and by season in temperate regions



Data source: French Agency for Environmental and Occupational Health Safety (AFSSET), "Weakening, collapse and mortality of bee colonies", November 2008 – Updated April 2009.

7 Fontaine C. et al. 2006. "Functional diversity of plant-pollinator interaction webs enhances the persistence of plant communities". PLoS Biol 4(1): e1 and "Diverse Pollination Networks Key to Ecosystem Sustainability". PLoS Biol 4(1): e12

8 Klein A.M., Vaissière B. et al. 2007. "Importance of pollinators in changing landscapes for world crops". Proceedings of the Royal Society B: 274, 303–313.

9 Simon Potts, Centre for Agri-Environment Research, University of Reading in "Bees and flowers decline in step", by Richard Black, Environment correspondent, 20 July 2006, BBC News website. See http://news.bbc.co.uk/2/hi/science/nature/5201218.stm

Wild pollinators are also at risk

Animal-based pollination services, from wild species like the bumble bee, foster reproductive potential and genetic resilience in many ecosystems. Although conclusive data indicates that some 1 200 wild vertebrate pollinators may be at risk[10], there is a lack of data on many invertebrate species that act as pollination agents.

Threats to certain invertebrate pollinator populations were reported in Europe as early as 1980[11], and confirmed in the 1990s. The regression mostly affected long-tongued species; this is likely due to the reduction in plants with long inner petals (e.g. Lamiaceae, Fabaceae, Scrophulariaceae). A British and Dutch study showed that in the United Kingdom (UK) and the Netherlands alone, since the 1980s a 70% drop in wild flowers requiring insect pollination has been recorded, as well as a shift in pollinator community composition[12]. In the UK, many pollinator species that were relatively rare in the past are becoming rarer, while more common species have become widespread. It was also found that 71% of butterfly species have decreased and 3.4% became extinct over the past 20 years, illustrating the highest net loss compared to native flowering plants (28% decrease in 40 years) and birds (54% decrease over 20 years) in the same UK region[13].

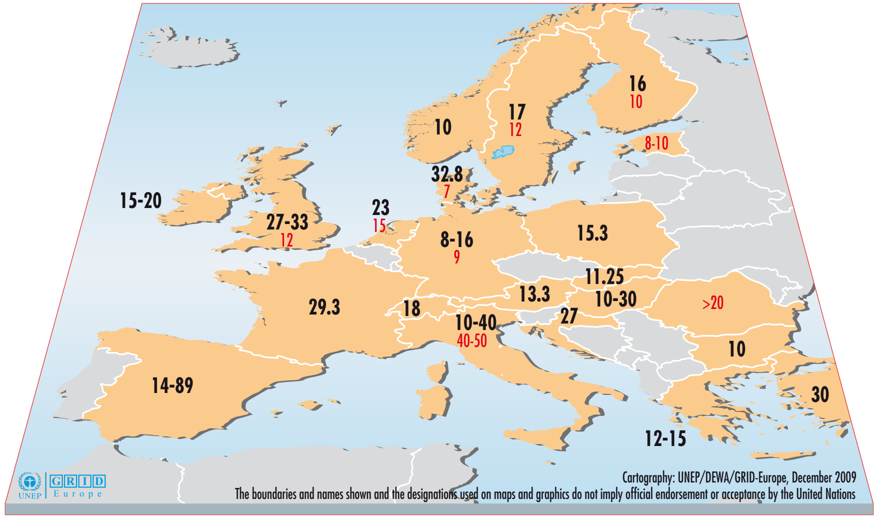
Bumblebees are highly social, like honeybees, but with smaller, less structured nests, that can consist of up to 1 000 bees. Bumblebee colonies are annual; the entire colony dies out each year and leaves only mated queens to hibernate through winter. The queen will start a new colony in spring. Bumblebees pollinate tomatoes, eggplants, peppers, raspberries, blackberries, strawberries, blueberries, and cranberries, just to name a few. Bumblebees are the only pollinators of potato flowers worldwide.

Honey bee, Apis mellifera. Photo courtesy of David Cappaert, Michigan State University, Bugwood.org

2.1 Europe

A decrease in managed honey bee colony numbers in Europe has been observed since 1965, but the pattern is diverse[14]. Since 1998, individual beekeepers have been reporting unusual weakening and mortality in colonies, particularly in France, Belgium, Switzerland, Germany, the United Kingdom, the Netherlands, Italy and Spain. Mortality has been extremely high when activity is resumed at the end of winter and beginning of spring.

Figure 3: European colony mortality



Data for colony mortality in European countries remains scarce or uneven. The most recent data compiled by the COLOSS working group indicates that winter losses are common and the main pathogen during this season is Varroa destructor[15]. Other factors such as pathogens[16] or pesticides[17] are also being studied.
Source: In black 2007-2008 mortality (COLOSS, Zagreb meeting proceedings), in red 2006-2007 mortality (EFSA members poll)

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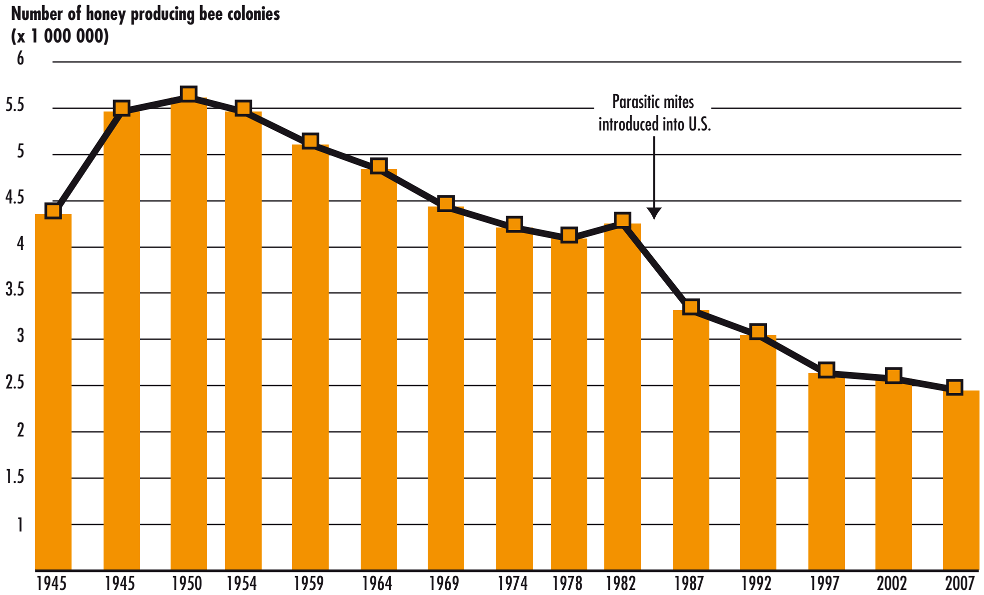
10 Allen-Wardell G., Bernhardt P. et al. 2008. "The Potential Consequences of Pollinator Declines on the Conservation of Biodiversity and Stability of Food Crop Yields". Conservation Biology, vol. 12, num. 1, p. 8-17.
11 Leclercq J. et al. 1980. "Analyse des 1600 premières cartes de l'Atlas Provisoire des Insectes de Belgique, et première liste rouge d'insectes menacés dans la faune belge". Notes Fauniques de Gembloux 4: 104 pp.
12 Biesmeijer J.C., Roberts S. P. M. et al. 2006. "Parallel Declines in Pollinators and Insect-Pollinated Plants in Britain and the Netherlands". Science: Vol. 313. no. 5785, pp. 351 – 354.
13 Thomas J. A., Telfer M. G. et al. 2004. "Comparative Losses of British Butterflies, Birds, and Plants and the Global Extinction Crisis". Science: Vol. 303. no. 5665, pp. 1879 – 1881.
14 Potts S.G. et al. 2010. "Declines of managed honey bees and beekeepers in Europe". Journal of Apicultural Research 49(1): 15-22.
15 Amdam, G. V., Hartfelder, K. et al. 2004. "Altered physiology in worker honey bees (Hymenoptera: Apidae) infested with the mite Varroa destructor (Acari: Varroidae): a factor in colony loss during overwintering?" J Econ. Entomol. 97, 741-747.
16 Higes, M., Martin-Hernandez, R. et al. 2009. "Honey bee colony collapse due to Nosema ceranae in professional apiaries". Environmental Microbiology Reports 10, 2659-2669.
17 Nguyen, B. K., Saegerman, C. et al. 2009. "Does imidacloprid seed-treated maize have an impact on honey bee mortality?". Journal of Economic Entomology 102, 616-623.

2.2 North America

A significant and constant decline in domestic honey bee colony numbers has been occurring during the past decades in this region[18, 19]. Losses of honey bee colonies since 2004 has left North America with fewer managed pollinators than at any time in the last 50 years. In this region, honey bees pollinate nearly 95 kinds of fruits such as almonds, avocados, cranberries and apples, as well as crops like soybeans[20]. In 2000, the value of crops pollinated by bees was estimated at US$ 14.6 billion in the USA alone[21].

Figure 4: US honey-producing colonies



Data source: U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) NB: Data collected for producers with 5 or more colonies. Honey producing colonies are the maximum number of colonies from which honey was taken during the year. It is possible to take honey from colonies which did not survive the entire year.

Since their introduction in the 1980s (see Figure 4), various mites are linked to drastic losses of colonies. Scientists have adopted the term "Colony Collapse Disorder" (CCD) to define this multi-factor syndrome affecting beehives annually, particularly where low numbers of adult bees with food supplies such as honey and bee bread and immature or capped brood bees are present.

While little build-up of dead bees in or around affected colonies has been observed, bee loss is due to the sudden early death of large numbers of adult worker bees[22], as the workforce that maintains the hive appears to consist of young adult bees. The queen is generally present and the remaining bees are reluctant to consume foods such as sugar syrup and protein supplements. It appears that dead and weak colonies are more likely to be found next to or in proximity to each other in CCD apiaries, which suggests that an infectious agent or exposure to a common risk factor may provoke CCD. During the 2006-2007 period, some 29% of 577 beekeepers across the USA reported CCD, with a loss of up to 75% of colonies[23]. Experts estimated that honey bee colony losses during the 2006-2007 and 2007-2008 autumn/winter periods at 31% and 36% respectively, exceeding the 10-20% losses that are considered normal.

Colonies can die in numerous ways. CCD only accounts for about 7% of losses in the USA[24] and even less in Europe. The loss of queen bees seems to be a much more common cause at about 25%.

2.3 Asia / Oceania

China has six million bee colonies; about 200 000 beekeepers in this region raise western honey bees (*A. mellifera*) and eastern honey bees (*A. cerana*). In recent years, Chinese beekeepers have faced several inexplicable and complex symptoms of colony losses in both *Apis* species. Certain losses are known to be caused by Varroa mites on *A. mellifera*, sacbrood viruses on *A. cerana* and *Tropilaelaps* mites on both species. However, other factors and mechanisms are being investigated, although no data has been published to date.

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[18] Ellis, J., Evans, J.D., Pettis, J.S. 2009. "Reviewing colony losses and Colony Collapse Disorder in the United States". Journal of Apicultural Research. 49:134-136.
[19] Aizen M. A. 2009. "The Global Stock of Domesticated Honey Bees Is Growing Slower Than Agricultural Demand for Pollination". Current Biology 19, 1–4, June 9.
[20] Stokstad E., "The Case of the Empty Hives", Science 18 May 2007 316: 970-972 [DOI: 10.1126/science.316.5827.970] (in News Focus).
[21] Morse R.A, Calderone N.W, 2000. "The value of honey bees as pollinators of U.S. crops in 2000", Cornell University, Ithaca, New York.
[22] "Colony Collapse Disorder (CCD) Working Group: Summary of purpose and responsibility" at http://maarec.cas.psu.edu/pressReleases/CCDSummaryWG0207.pdf
[23] Stokstad E., "The Case of the Empty Hives", Science 18 May 2007 316: 970-972 [DOI: 10.1126/science.316.5827.970] (in News Focus)
[24] vanEngelsdorp D., Hayes J., Underwood R. M. and Pettis P.S. 2010. "A survey of honey bee colony losses in the United States, fall 2008 to spring 2009". Journal of Apicultural Research 49(1): 7-14 (2010)

Beekeepers in Japan raise both *A. mellifera* and *A. cerana*, and 25% of beekeepers have recently been confronted with sudden losses of their bee colonies[25].

A. mellifera was introduced repeatedly in Australia during the 19th century. Natural honey bee populations that were established from managed colonies are now found throughout the country. The Varroa mite has not yet been introduced into Australia. Bee hives have been placed at 26 ports around the country, which are checked regularly for infection to better monitor the potential arrival of this threat. Another measure is the placement of empty "bait" hives to attract bees that come off ships. A lesser risk is posed by *A. cerana* which may arrive from Japan, the Republic of Korea, or Thailand[26]. After the introduction of *A. mellifera*, and the recently arrived *Bombus terrestris*, Australia maintains strict quarantine barriers, along with thorough research and funding before the introduction of new pollinator species. Until now, there are no confirmed reports of increased honey bee losses.

2.4 Africa

Egyptian beekeepers based along the Nile river have reported symptoms of CCD[27]. One scientific experiment involved moving certain affected colonies to another habitat. The results have shown that a clean environment with diverse vegetation, compared to the original location, has an important role in defeating the symptoms of CCD. Until now, there are no other confirmed reports of honey bee losses from Africa.

3. Driving forces of pollinator population instabilities

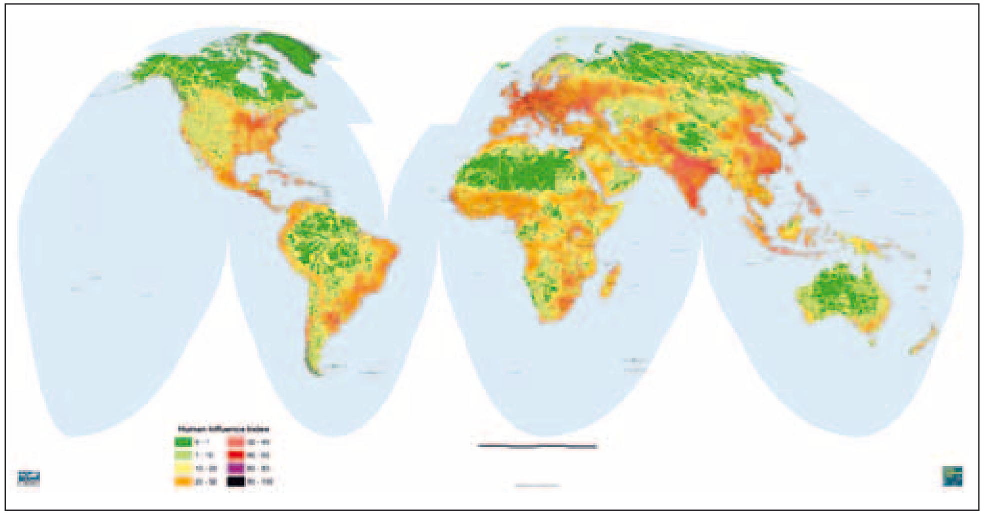
3.1 Habitat deterioration

Degradation

Human activities have impacted the landscape through fragmentation, degradation and destruction of natural habitats and the creation of new anthropogenic ones. Changes in land-use and landscape structure affects pollinators, target plants and their interactions at individual, population and community levels. Degradation and fragmentation of natural habitats are considered as key adverse changes for pollinator populations[28].

Firstly, this can lead to the reduction of food sources for all pollinator species. When large habitats are fragmented into small isolated patches, food sources become more scarce for resident animals. Populations may then decline to the point that they are no longer able to benefit plants[29]. As certain wild pollinators need undisturbed habitat for nesting, roosting, foraging and sometimes specific larval host plants, they are very susceptible to habitat degradation and fragmentation in particular.

Figure 5: Human Footprint



Data Source: CIESIN, NASA, SEDAC, 2000:
Human Footprint mapping project shows the cumulative effect of six billion people on the planet, illustrating human impact on every square kilometre of the Earth. In this map, human impact is rated on a scale of 0 (minimum) to 100 (maximum) for each terrestrial biome. A score of 1 indicates the least human influence in the given biome. However, because each biome has its own independent scale, a score of 1 in a tropical rainforest might reflect a different level of human activity than in a broadleaf forest.

[25] Natural News 28 April 2009, "Honey bee Collapse Strikes Japan, Up to Fifty Percent of Honey bees Gone". www.naturalnews.com/026151_Japan_honey bees_honey.html
[26] Cunningham S. A. et al., 2000. "The future of pollinators for Australian agriculture". Aust. Journ. Agric. Res. 53, 893-900.
[27] A. R. Hassan1 2009,"Proceedings of the 4th COLOSS Conference".
[28] Thomas J. A, Telfer M. G. et al. 2004. "Comparative Losses of British Butterflies, Birds, and Plants and the Global Extinction Crisis". Science: Vol. 303. no. 5665, pp. 1879 – 1881
[29] Hendrix S.D, 1994, "Effects of population size on fertilization, seed production, and seed predation in two prairie legumes". North American Prairie Conference Proceedings 13: 115-119.

In parallel, The International Union for Conservation of Nature (IUCN) predicts a global loss of 20 000 flowering plant species within the coming decades. Undoubtedly, this will lead to the decline of co-dependent pollinators who need these plants for survival, as most species are highly dependent on habitat diversity for their survival.

Increased pathologies

In the wild, various pathogens have crossed over from commercially managed species of bumblebees used for greenhouse pollination. This has contributed to a decline in some native bumblebees. Furthermore, unhealthy ecosystems can facilitate the development of parasites which may affect both managed and wild pollinators. Consequently, the preservation or restoration of pollinators and their services requires a holistic approach from a local to landscape level that reflect the spatial distribution of resources and the foraging and dispersal movements of the relevant organisms[30].

Invasive Species

The external parasitic mite, *Varroa destructor*, is the most serious threat to apiculture globally. Recognised as an invasive species, it has shifted hosts from *A. cerana* to *A. mellifera*. About the size of a pinhead, it feeds on bees' circulatory fluid and spreads from one hive to another. The parasite can spread viral diseases and bacteria. If left uncontrolled, it will almost certainly lead to the premature death of colonies within three years. Discovered in Southeast Asia in 1904, today it has spread nearly worldwide.

Other invasive acari species are also of concern, such as the small hive beetle (*Aethina tumida*), which is endemic to sub-Saharan Africa. It has colonised much of North America and Australia and is now anticipated to arrive in Europe. This beetle and its larvae cause damage to honeycomb, stored honey and pollen. Another external mite is the parasite *Tropilaelaps clareae*, which also originated from Southeast Asia and has shifted from *A. dorsata* to *A. mellifera*. However, its distribution has been quite limited to date.

Figure 6: Invasive Asian hornet presence in France

Source: (Villemant C., Rome Q. & Haxaire J. 2009. Le Frelon asiatique (Vespa velutina). In Muséum national d'Histoire naturelle [Ed]. 2009. Inventaire national du Patrimoine naturel, site Web. http://inpn.mnhn.fr

Competition from non-native hymenoptera species is also of concern for pollinators, notably the Africanised bee in the USA and the Asian hornet (*Vespa velutina*) in Europe. The Asian hornet, which mainly feeds on European honey bees, has now colonised nearly half of France (Figure 6). Research is being conducted to limit its expansion and impact on honeybees.

Pollution and other threats

Air pollution hampers the symbiotic relationships between pollinators and flowers. Although daytime insects depend primarily on vision to find flowers, pollutants affect