Pollination – a Key Service Regulating Ecosystems

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There has been much debate about whether Albert Einstein did or did not say that "*if the bee disappeared off the surface of the globe then man would only have four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man*". Most probably he never made this statement but if he did then he had insight way ahead of his time. It was not until much later that it was recognised that bees and other pollinators play a central role in the maintenance of ecosystem functioning (Williams et al. 1991, Millenium Ecosystem Assessment 2005) and not until 1997 that Costanza et al. many of made the first estimate of the value of their services.

Europe has a wide variety of insect pollinators including honeybees (*Apis mellifera*), bumblebees, solitary bees, butterflies, and some beetles and flies. Honeybees, some bumblebees and solitary bees, are actively managed. However, the majority of vast majority of pollinating insects species are 'wild' and not managed.

Without insect pollination entomophilous (insect-pollinated) plant populations all over the world would decline and eventually disappear and with it all the organisms depending directly or indirectly on them, most probably ourselves included. Whether this would take four years, as Einstein is supposed to have said, is unlikely but the collapse of terrestrial ecosystems would be inevitable in the long-term.

It is well-known that the majority of higher plants, including many crop species, depend on insect pollinators for reproduction (e.g., Klein et al. 2007). These plants provide forage for pollinators, mostly in the form of nectar and pollen, in return for the dispersal of their male gametes, the pollen. Even many self-compatible plant species (e.g., tomatoes) benefit from out-crossing or the facilitation of self-pollination by insect pollinators.

Pollination is therefore an important ecosystem service without which most wild plants and many crops would not be able to produce seeds. A recent study by Gallai et al. (2009) within the ALARM project estimated the global value of pollination to agriculture to be € 153 billion per year.

It is estimated that more than 150 (84%) of European crops are directly dependent upon insects for their pollination (Williams 1994). European crops for which the number of fruits and seeds and their quality are dependent upon, or enhanced by, insect pollination (Corbet et al. 1991) include:

- Fruits – apple, orange, pear, peach, melons, lemon, strawberry, raspberry, plum, apricot, cherry, kiwifruit, mango, currants
- Vegetables – carrot, potato, onion, tomato, pepper, pumpkin, field bean, French bean, eggplant, squash, cucumber, and soy bean
- Seeds and nuts – sunflower, almond, walnut and chestnut
- Herbs – basil, sage, rosemary, thyme, coriander, cumin and dill
- Industrial crops – cotton, oilseed rape, white mustard, and buckwheat
- Fodder crops for animals – alfalfa, clover and sweetclover
- Essential oils – chamomile, lavender, and evening primrose

Many farmers obtain better pollination services by bringing large numbers of managed bees (e.g., honeybees or bumblebees) to crop fields or greenhouses to raise their yield. Unfortunately, beekeepers' numbers are dropping and as can be seen from the article "Severe Declines of Managed Honeybees in Central Europe" by Potts et al. (this atlas, pp. 184f.) the supply of honeybees has been consistently declining in many parts of Europe in the past decades. Similar trends can be observed in North America (USDA National Agricultural Statistics Service 1977, 2006; National Research Council (U.S.) Committee on the Status of Pollinators in North America 2007).

There are several possible causes for this including a variety of pests and diseases (e.g., the hive beetle, *Varroa* mites, and many viruses), inappropriate use of pesticides, lack of high quality forage, and colony collapse disorder. These multiple drivers have devastated the honeybee industry in the US and parts of Europe with loss of livelihoods for beekeepers and potential risks for crop and fruit producers.

Many studies have shown that unmanaged, wild pollinators, are very valuable crop pollinators, but far less is known about their ecology and contribution to crop production (e.g., Greenleaf & Kremen 2006, Klein et al. 2007, 2008). In addition, unmanaged wild pollinators constitute the vast majority of the pollinator community of wild plants. As has been shown many of these pollinators are in decline in the United Kingdom and the Netherlands and so are the out-crossing plant species they visit (Biesmeijer et al. 2006). Although the United Kingdom and the Netherlands are the only countries for which this decline has so far been demonstrated, with the help of historical data the problem is most likely to be much more widespread (Banaszak 1995, Biesmeijer et al. 2006).

It is still not fully clear what drives the decline of unmanaged pollinators but most likely it is a combination of causes. Important drivers include habitat loss, fragmentation and degradation which affect the availability of key foraging and nesting resources needed for bee populations. In addition, changes in agriculture practices such as the planting of monocultures of wind-pollinated crops, which provide no resources for bees, can also have negative impacts. The increased use of agrochemicals may also be a major pressure on wild pollinators; pesticides may have direct impacts through mortality or indirect, sub-lethal effects, by modifying flight and searching behaviour which makes foraging less efficient. Similarly, fertilizer applications can increase soil fertility and thereby modify wild plant community structure in agro-ecosystems by reducing diversity of floral food sources.

Strong concerns about the impact a decline or even the loss of pollination services could have on dependent organisms have been reported (Diaz et al. 2005, Steffan-Dewenter et al. 2005, Biesmeijer et al. 2006, but see Ghazoul 2005) and have been formally recognised within the Convention on Biological Diversity as the *International Initiative for the Conservation and Sustainable Use of Pollinators* (*IICSUP*) in the 'In-depth review of the programme of work on Agricultural Biodiversity' at the 9th Conference of Parties (COP 9 Decision IX/1 2008) and the U.S. National Research Council's Committee on the Status of Pollinators in North America (2007).

Given the enormous potential environmental, social and economic impacts a decline in pollination services may have, it is surprising that so few studies have addressed this subject in any depth. This chapter aims to extend our knowledge and highlight some important aspects of wild and managed pollinators, their possible decline and the fate of the entomophilous plant species they visit.

Until now, due to the lack of a standardised set of methods for assessing the decline of pollinators, it was often difficult to compare studies or to conduct them in the first place. The article by Westphal et al. (this atlas, pp. 170f.) provides us with a toolkit of field-tested methods and their evaluation designed for large-scale and long-term monitoring schemes. If adopted by the scientific community it will greatly assist further research into pollinator decline. Adoption of standardised methods would also underpin the development of local, national, and regional monitoring programmes which would allow the long-term assessment of the status and trends of pollinators. The need to collect baseline data for such programmes is of paramount importance if we are to understand the fate of European pollinators and direct mitigation strategies towards halting losses and potentially reversing any declines.

Focus on key guilds within the pollinator fauna is described by Budrys et al. (this atlas, pp. 172f.) who look at cavity-nesting Hymenoptera across Europe using small trap-nests on trees and buildings. They investigate the influence of landscape complexity and agriculture on the abundance and biodiversity of these important pollinators.

Nielsen et al. (this atlas, pp. 174f.) assess the impact of pollinator shifts on wild plants and explore how plant reproduction and pollinator activity are controlled by plant population structure at different spatial scales. This aspect has important implications for the conservation of plants and their pollinators as wild plant populations must provide enough floral resources to attract and support sufficient pollinators to ensure plant recruitment and species survival.

Meyer & Steffan-Dewenter (this atlas, pp. 176f.) present a case study from Germany looking at possible drivers of pollinator loss. They examine the impact of landscape effects on pollinator abundance and biodiversity in relation to their specific life history traits. This study is especially timely as the intensification of agriculture in recent decades along with the abandonment of traditional land-use practices has caused a substantial decline in habitats that are commonly species-rich such as calcareous grasslands.

Szentgyörgyi et al. (this atlas, pp. 178f.) look at commercially available bumblebees, such as *Bombus terrestris*, which, as superior pollinators, are regularly used in greenhouses in Central Europe and increasingly elsewhere. The authors point out the risks such introductions may pose to the local biodiversity, also as vectors of various parasites, which can in turn infect native bumblebees. In the study presented in this chapter the authors test whether commercial bumblebees in greenhouses escape and introgress into the wild population. Furthermore, they test whether wild bumblebees near greenhouses show higher *Nosema bombi* infection levels than control bumblebees that have not been in contact with commercial bumblebees.

Rortais et al. (this atlas, p. 180) investigate the status of the black honeybee (*Apis mellifera mellifera*), which is native to western Europe and is threatened in many places by commercial bee breeding. They point out the difficulties in distinguishing them from other subspecies of the European honeybee and present a geometric morphometric tool which aids identification and constitutes an important step towards effective conservation of the black honeybee in Europe.

Rortais et al. (this atlas, p. 181) present another study on the distribution of the recently introduced alien, the Asian hornet (*Vespa velutina*), in south-western France. The Asian hornet is spreading rapidly and poses a serious threat to the provision of pollination services in the invaded areas as they attack honeybee colonies.

Jaffe & Moritz (this atlas, pp. 182f.) raise the interesting question whether or not the honeybee should be considered a domesticated animal. They argue that where the honeybee is native, evidence for actual competition between the honeybee and "wild" bees is rare. They present data on hive densities throughout Europe and discuss socioeconomic reasons for regional differences. Furthermore, they suggest policy guidelines for the conservation of honeybee subspecies and sustainable beekeeping in Europe.

Potts et al. (this atlas, pp. 184f.) present data on the relative changes in number of colonies, number of beekeepers and amount of honey produced in 20 European countries between 1965-2005 and 1985-2005. They discuss possible reasons for the decline in honeybee colonies and beekeepers taking into account also socioeconomic aspects. The economic and biodiversity implications this decline of honeybees in combination with the decline of non-managed pollinators may have on the provision of pollination services are also pointed out. Since the days of Albert Einstein we have learned a lot about pollinators, their services, their decline and its assessment, not least due to the ALARM project and the pollinator related studies therein of which the following articles in this chapter provide an overview.

References

Banaszak J (1995) Natural Resources of wild bees in Poland and an attempt at estimation of their changes. Pages 11-26 *in* J. Banaszak, editor. Changes in Fauna of Wild Bees in Europe. Pedagogical University, Bydgoszcz.

Biesmeijer JC, Roberts SPM, Reemer M, Ohlemüller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J, Kunin WE (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351-354.

Convention on Biological Diversity (www.biodiv.org/default.shtml). COP 9 Decision IX/1. 2008. http://www.cbd.int/decisions/?m=COP-09&id=11644&lg=0.

Corbet SA, Williams IH, Osborne JL (1991) Bees and the pollination of crops and wild flowers in the European Community. *Bee World* 72: 47-59.

Costanza R, D'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, Van Den Belt M (1997) The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Diaz S, Fargione J, Chapin FS, Tilman D (2005) Biodiversity Loss Threatens Human Well-Being. – In: Hassan R, Scholes R, Ash E (Eds), Ecosystems and Human Well-Being: Current State and Trends. Island Press, Washington, DC, 297-329.

Gallai N, Salles JM, Settele J, Vaissière BE (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68: 810-821.

Ghazoul J (2005) Buzziness as usual? Questioning the global pollination crisis. *Trends in Ecology and Evolution* 20: 367-373.

Greenleaf SS, Kremen C (2006) Wild bee species increase tomato production and respond differently to surrounding land use in Northern California. *Biological Conservation* 133: 81-87.

Klein A-M, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T (2007) Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* 274: 303-313.

Klein AM, Cunningham SA, Bos M, Steffan-Dewenter I (2008) Advances in pollination ecology from tropical plantation crops. *Ecology* 89: 935-943.

Millenium Ecosystem Assessment (2005) Ecosystems and Human Well-Being, Synthesis. Island Press, Washington, D.C.

National Research Council (U.S.) Committee on the Status of Pollinators in North America (2007) Status of pollinators in North America. National Academies Press, Washington, D.C.

Steffan-Dewenter I, Potts SG, Packer L (2005) Pollinator diversity and crop pollination services are at risk. *Trends in Ecology and Evolution* 20: 651-653.

Usda National Agricultural Statistics Service (1977) 1976 Honey production report. United States Department of Agriculture, Washington, DC.

Usda National Agricultural Statistics Service (2006) 2005 Honey production report. United States Department of Agriculture, Washington, DC.

Williams IH, Corbet SA, Osborne JL (1991) Beekeeping, wild bees and pollination in the European Community. *Bee World* 72: 170-180.

Williams IH (1994) The dependence of crop production within the European Union on pollination by honeybees. *Agricultural Zoology Reviews* 6: 229-257.