ECOLOGY

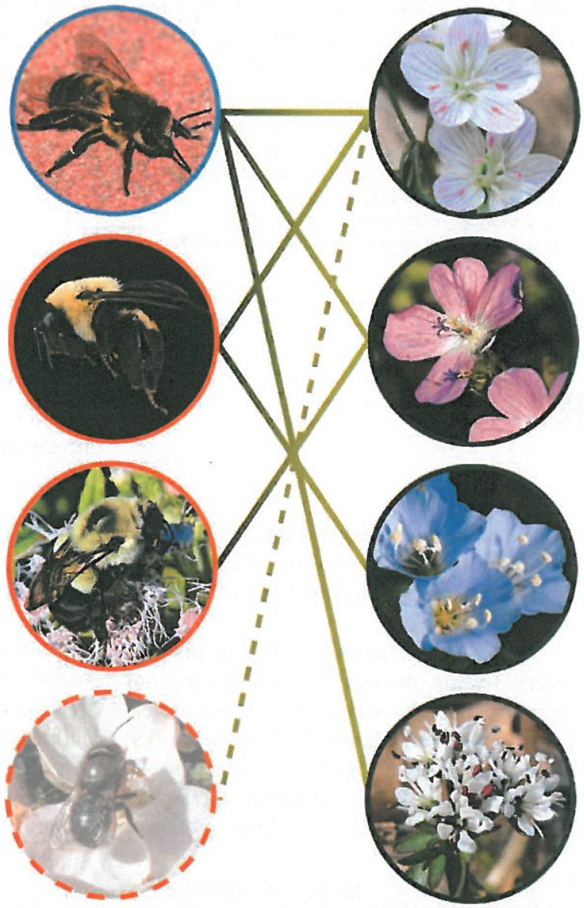
# The Global Plight of Pollinators

Wild pollinators are in decline, and managed honeybees cannot compensate for their loss.

**Jason M. Tylianakis**

Three-quarters of global food crops depend at least partly on pollination by animals, usually insects (*1*). These crops form an increasing fraction of global food demand (*2*). Given this importance, widespread declines in pollinator diversity (*3*) have led to concern about a global "pollination crisis" (*4*). However, others have argued that this concern is premature and that conservation action cannot yet be justified on the basis of deteriorating pollination (*5*). Are concerns of a pollinator crisis exaggerated, and can we make do with better management of honeybee colonies? Two articles in this issue provide compelling answers to these questions. On page 1611, Burkle *et al.* demonstrate that native wild pollinators are declining (*6*). On page 1608, Garibaldi *et al.* show that managed honeybees cannot compensate for this loss (*7*).

The arguments against a pollination crisis are based on the number of staple crops (such as rice, maize, and wheat) that do not require animal pollination. Furthermore, it has been questioned whether pollination is actually declining globally. If pollinators do decline or go extinct, other generalist species may be able to fill the gap (*5*), assisted by domesticated honeybees, which are increasing in numbers globally despite declines in certain regions (*2*). Do these arguments hold up? Can we get by with just honeybees?



**The role of wild pollinators.** Schematic of a plant-pollinator network such as that studied by Burkle *et al.* (*6*). Circles depict plant or pollinator species. Each solid line represents an interaction between a plant and a pollinator. Dashed lines and circles represent species and interactions that have gone extinct. Garibalidi *et al.* (*7*) found that the honeybee (blue circle) was less effective than many of its wild pollinator counterparts (orange circles).

To measure the extent to which environmental changes over the past 120 years have disrupted plant-pollinator interactions, Burkle *et al.* revisited sites in Illinois in 2010/2011 that were sampled in the late 1800s and in the 1970s. They found that half of the bee species present historically were absent and that less than one-quarter of the historical plant-pollinator interactions were still observed. Moreover, the quantity and quality of pollination experienced by plants has also declined. The herbaceous perennial flower *Claytonia virginica* now receives a quarter of the pollinator visits it received in the 1970s. Those pollinators that do still visit are less faithful to that species (that is, they carry pollen from many other plants), which can negatively affect pollination success.

Using a network approach to study plant-pollinator interactions (see the figure), the authors found changes that suggest that overall pollination will be less resistant to extinction in the future. Present-day interactions not recorded in the historical samples tended to involve species with historically narrow diets. This contrasts with the concept of preferential attachment in networks, whereby highly connected species should be more likely to acquire new interactions with others. The opposite finding by Burkle *et al.* (*6*) may be explained by changes to pollinator and plant phenology (*8*) and suggests that even seemingly specialist species may have an important role in filling the pollination gap after extinctions. Burkle *et al.* also found that species loss was nonrandom, such that specialists, parasites, cavity-nesters, and species that participated in weak historic interactions were most likely to go extinct. This result, along with recently discovered nonrandomness in the loss of pollinator interactions in fragmented habitats (*9*), foreshadows a systematic alteration of global pollination networks under a suite of environmental changes.

From a food production standpoint, the decline of wild pollinators could be ignored if honeybees can do the same job. It has even been suggested that honeybees can do the job better (*10*, *11*). If this were true, then we should focus all our efforts on protecting honeybees and invest as much as possible in combating colony collapse disorder, Varroa mite, and any other threats to the species charged with protecting global food security (*11*).

However, the landmark study by Garibaldi *et al.* suggests that putting our hopes and efforts into honeybees may not yield the desired results. The authors examined pollination of 41 crop systems from 600 field sites on every continent except Antarctica. They found that, even though honeybees frequently deposit a lot of pollen, they apparently do so ineffectively. The percentage of flowers that produced fruit was relatively low when flowers were visited by honeybees, and increased visitation by honeybees only increased fruit production in 14% of the systems surveyed. In contrast, the increase in fruit production after visitation of flowers by wild insects was twice as great as that produced by honeybees, and flowers pollinated by wild insects were more consistent

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in their fruit production. This pattern was generally consistent across a great variety of the most important pollination-dependent crops. The benefit associated with wild bees did not depend on whether or not honeybees were present. Thus, conservation of wild bee diversity will be paramount even when managed honeybees are used.

The two studies (*6*, *7*) highlight the effects of environmental change on pollinator-plant interactions and the risks of putting all our eggs in one basket for pollination. Garibaldi *et al.*'s finding that fruit set increased and became less variable with pollinator diversity, independently of visitation by honeybees, highlights the importance of in situ biodiversity for food production. This challenges the validity of land-sparing conservation approaches (*12*), which advocate the protection of biodiversity only outside farmed areas, and the further intensification of agricultural land use. Above all, the studies show conclusively that biodiversity has a direct measurable value for food production and that a few managed species cannot compensate for the biodiversity on which we depend.


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COMPUTER SCIENCE

# Toward a Green Internet

**Methods for energy efficiency savings will be needed to meet the growing demands of increasing Internet usage.**

**Diego Reforgiato Recupero**

Information and communication technology (ICT) has been extensively used to monitor energy use in a variety of applications. However, the use of ICT itself has led to huge increases in energy consumption. Today, we are witnessing a rise of energy costs, customer increase, more on-demand services using cloud architectures, mobile Internet, a diffusion of broadband access, and a growing number of services offered by internet service providers (ISP). Consequently, energy efficiency is quickly becoming a high-priority issue for the Internet.

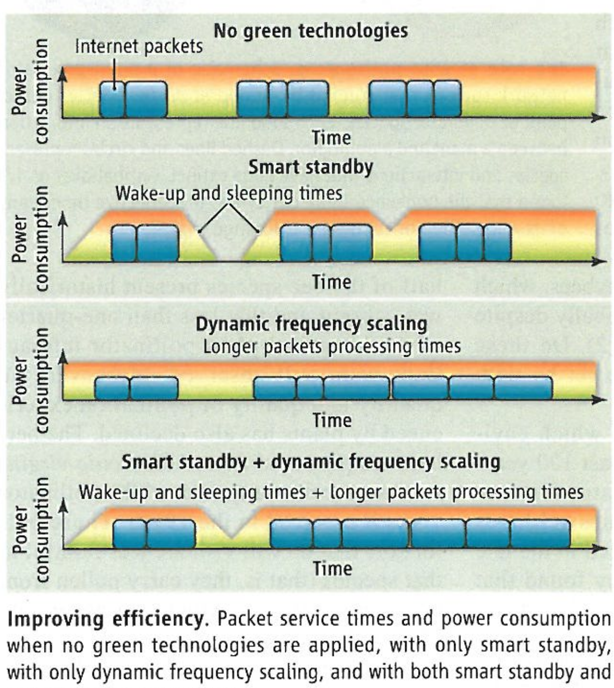
Telecom companies such as Telecom Italia used over 2 terawatt hours (TWh) in 2006 (about 1% of the entire Italian energy demand), increasing by ~8% compared with 2005 and ~12% in 2004 (*1*, *2*). Comparable numbers were reported by Telecom France and British Telecom, by Verizon in the United States, and by NTT in Japan. In Germany, 20% of Internet energy usage was due to cooling systems. In 2005, European Internet operators had an overall network energy requirement equal to 14 TWh, increasing to 21 TWh in 2010, and projected to rise to 36 TWh in 2020 if no green network technologies are embraced. Moreover, the world's data centers consumed over 270 TWh in 2012; it is estimated that they will consume 19% more energy in the next 12 months than they have in the past year (*3*). The cost of new equipment has been overtaken by the cost of the required power and cooling infrastructure and will soon be exceeded by the lifetime energy costs (*4*).

Although Internet traffic volume doubles every 3 years, the increase in usage has not been matched by a similar increase in network energy efficiency. Current networks, devices, links, and data centers are provisioned with hardware and software designed for peak loads that do not include any power management capabilities. As a consequence, the overall power consumption remains more or less constant for differing Internet traffic levels even while peak loads rarely occur.

As the Internet evolves, it is apparent that energy efficiency needs to be addressed.

Over the past 3 years, a number of international research projects (*5*–*7*) have been initiated, with specific efforts including methods to redesign the power management features of network devices to improve efficiency (*8*, *9*). Two of the most exciting new techniques are smart standby (*10*) and dynamic frequency scaling (also known as CPU throttling). The former will allow unused parts of a network device to be put into very low power states, where only very basic functionalities are performed. This method is key for reducing energy consumption because it will allow switching some portion of the network to a sleep mode in a smart and effective way.

Dynamic frequency scaling allows us to trade off the energy consumption and processing capacity of internal blocks while satisfying the current traffic load and quality of service constraints. This ensures that when the




**Improving efficiency.** Packet service times and power consumption when no green technologies are applied, with only smart standby, with only dynamic frequency scaling, and with both smart standby and dynamic frequency scaling.

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