"The Birds and the Bees"—How Pollinators Help Maintain Healthy Ecosystems

Written Testimony of

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Mr. Chairman and members of the Subcommittee, thank you for the opportunity to talk to you about the status of pollinators in North America. My name is May Berenbaum and I am Swanlund Professor and Head of the Department of Entomology at the University of Illinois at Urbana-Champaign. I recently chaired the National Research Council Committee on the Status of Pollinators in North America. Reports of apparent pollinator declines around the world over the past decade led to concerns in the United States about a brewing "pollinator crisis." The National Research Council, the operating arm of the National Academy of Sciences chartered to provide objective scientific analysis and advice to the government, was asked by the U.S. Department of Agriculture and U.S. Geological Survey to convene a committee to examine data on pollinator status in North America to determine whether pollinators are experiencing declines, what the causes of such declines may be, what the potential consequences could be in agricultural and natural ecosystems, and whether and how declines can be reversed or prevented.

The status of pollinators is a matter of national interest because the lives of over 200,000 plant species worldwide depend on pollination, the process by which pollen grains, containing male sex cells, are transferred to stigmas, or female floral parts, to bring about fertilization, a necessary step in producing seeds. Pollen delivery presents a challenge to flowering plants, most of which spend their lives rooted to the ground, and approximately three-fourths of them rely on mobile animal partners—pollinators—to achieve this end. Beyond its other attractions, sexual reproduction provides opportunities for producing genetic variability, which allows organisms to adjust to changing environmental conditions. As ecological interactions go, animal-mediated pollination tends to be rapid, intermittent, and easily overlooked; that animals can serve as pollinators was not even widely recognized by the scientific community until the 19th century.

Evidence for decline

The committee determined that, if "decline" is defined as a systematic decrease in population size over time, there is evidence that at least some pollinators in North America are, in fact, in decline. The strength of the evidence, however, varies with the group. Pollinators include in their ranks about1,200 species of vertebrates across three classes and at least 200,000 species of insects in six orders. Despite the utter centrality of pollination to terrestrial life, there is an extraordinary dearth

of dependable data on pollinator populations in general. The most compelling evidence for pollinator decline is available for *Apis mellifera*, the imported European honey bee, a semi-domesticated species whose pollination services are actively managed and available for purchase. Although the estimated value of honey bee pollination ranges in the billions of dollars, record-keeping practices is problematical even for this species. Data problems notwithstanding, a pattern of decline is clear and was the subject of an earlier hearing held by the House Agriculture Subcommittee on Horticulture and Organic Agriculture.

Among wild pollinators, patterns of population change are clearest for large, warm-blooded species. Bats, for example, are important pollinators for a variety of North American plants, including many species of columnar cacti, balsa trees, and agaves. Declines in bat populations have been so dramatic that two of the three U.S. pollen-feeding species are now listed as endangered under the terms of the U.S. Endangered Species Act. Among the cold-blooded pollinators, charisma – general likeability in the public eye—appears to influences the probability that any evidence of decline is available. Aesthetically pleasing butterflies, e.g., constitute the majority of listed endangered insects. Because butterflies have long attracted the attention of both the scientific and lay communities, they have been the focus of the majority of long-term monitoring efforts in the U.S. that have documented distribution changes, declines, and local extinctions. In one California study, a 29-year census of butterfly species showed nearly a 40% decline in species diversity. Although decline was evident by the 13th year of the study, it did not achieve statistical significance until the 23rd year, demonstrating the necessity for long-term monitoring to detect trends in population size, an inherently variable trait.

Moths, which are generally nocturnal and drab, outnumber butterflies in the U.S. by a substantial margin but are outnumbered on the endangered species list by their more colorful relatives. Moths are important pollinators in a variety of plant communities; within southwestern U.S. deserts, hawk moths are principal pollinators of many plants, including night-blooming cacti, desert lilies, evening primroses, and wild tobacco. Although long-term population data are essentially nonexistent for most charisma-challenged moth species, there is evidence for the extinction of at least one species of hawk moth in Hawaii; two species of native lobeliads that grow on sheer cliff faces consequently must be hand-pollinated by humans to produce seeds and stave off extinction.

Many other pollinators could well be in decline, but data providing unambiguous documentation of trends are simply not available. While honey bees have deservedly been in the news of late, there are actually over 3,500 other species of bees that pollinate crops and wild plants in North America. Such native bee pollinators as digger bees, sweat bees, alkali bees, squash bees, leafcutter bees, carpenter bees, mason bees, and shaggy fuzzyfoot bees are hardly household names but their pollination activities enliven many households. Alkali bees can pollinate onions, mint, and celery, carpenter bees pollinate canola and pepper, leafcutter bees contribute to pollinating the alfalfa that provides forage for dairy and beef cattle, mason bees can pollinate apples and cherries, squash bees can pollinate pumpkins, and shaggy fuzzfoot bees can pollinate apples and blueberries. Wild bee pollination of U.S crops has been estimated to be worth over $3 billion annually. Their contribution to pollination of native plant communities is likely indispensable but for most species no evidence of population decline exists because their abundance has never been measured over time.

Among native bees, bumble bees are exceptional in that there are some indications of significant declines. The native long-tongued bumble bees pollinate a diversity of wild plants, particularly those with deep, tubular flowers, and serve as complementary pollinators for crops such as watermelon, cucumber, berries and sunflowers. Declines and regional absences of some species have been noted within the past decade and The Xerces Society for Invertebrate Conservation has

placed four U.S. bumble bee species on its list of at-risk pollinators. Again, the absence of long-term monitoring or historical baseline data for bumble bees (and most other species of wild bees in North America) makes definitive determinations of population status difficult if not impossible but it appears likely that two species are or may soon be extinct.

In contrast with the U.S., Europe has a well-established tradition of standardized monitoring of pollinators by both scientists and naturalists. The Bees, Wasps and Ants Recording Society (BWARS) was established in 1978 in the United Kingdom expressly to obtain reliable population and distribution data to inform and promote research and conservation efforts (http://www.searchnbn.net/organisation/organisation.jsp?orgKey=222). The ALARM project (Assessing Large Scale Risks for Biodiversity with Tested Methods: http://www.alarmproject.net/alarm/objectives.php) was initiated in 2004 to document changes in the abundance and distribution of pollinators across Europe. These and other extensive studies show unambiguous patterns of decline in species richness and distribution of many bees, particularly long-tongued species.

Even less well known (and far less charismatic) than native bees are the 17,460 species of flies in North America that are pollinators. Wild plants pollinated by flies include many irises, stonecrops, and pipevines; flies are especially important pollinators in alpine habitats. Fly pollination is agriculturally important as well; they are the sole pollinators of cacao, the source of all things chocolate, and also contribute to the pollination of several minor crops, including onions. Although data are insufficient to document population declines in flower-visiting flies in the U.S., there is a clear pattern of decline in the number of entomologists who can even identify these flies, much less monitor them. The last assessment of New World flies is almost a decade old; fewer than 25% of the species have been well-studied and no field guides for flies exist.

In view of the pervasive absence of reliable data and the virtual nonexistence of efforts to acquire reliable data, our committee made a series of recommendations. Because populations cannot be monitored without the taxonomic expertise required to identify the relevant pollinators, the committee recommended that federal funding agencies **expand basic research on the systematics of pollinators and on the development of rapid identification tools.** Also, because thorough, systematic monitoring efforts in Europe have successfully provided historical baselines for assessing declines in pollinator abundance and diversity and because no comparable effort has been undertaken in the U.S. the committee also recommended that **the federal government establish a network of long-term pollinator-monitoring projects that use standardized protocols and joint data-gathering interpretation.** High priority should be given to a rapid, one-time assessment of the current status of wild pollinators in North America to establish a baseline for long-term monitoring.

Causes of declines

In those cases in which declines could be documented, the causes of decline could be identified definitively only rarely. The decline in bat populations is demonstrably associated with destruction of cave roosts. Native bumble bee decline appears to result at least in part from infection with non-native protozoan parasites, including *Nosema bombi* and *Crithidia bombi*, likely originating from commercial bumble bees imported from Europe for greenhouse pollination. Risks of future infections can be reduced by requiring certification of disease-free status prior to importation.

For many groups of pollinators, however, many interacting ecological and environmental challenges appear to be leading to a death by a thousand cuts. Declines are associated with habitat loss, fragmentation, and deterioration, nontarget pesticide exposure, and invasive species. Changes in ranges and distributions of pollinators and the plant species they visit that lead to loss of synchrony (possibly because of global climate change) and to disruption of migratory routes by urbanization and

other forms of development have been implicated in reductions in numbers of hummingbirds, nectar-feeding bats, and some butterflies and moths.

Consequences of decline

The economic consequences of pollinator decline are most easily estimated in the context of agriculture. The contributions of one species alone—the honey bee—facilitate production of over 90 crops in the U.S. and amount to more than $15 billion per year. In many cases, an improved understanding of the mechanics of pollination has led to the commercialization and expansion in production of many crops. California, for example, is today a leader in worldwide fig production but the fig industry became established there in the late nineteenth century only after fig wasps, essential pollinators, were imported for pollination.

To estimate the economic and ecological value of wild pollinators and predict the consequences of their losses in natural communities is considerably more challenging. Such calculations are complicated both by the enormous number of species involved and the paucity of information available for most of those species. For a substantial proportion of plants in most uncultivated North American terrestrial communities, the precise identity of the suite of effective pollinators has not been established. Although many species may visit a particular flower, only a small proportion of visitors may have the capacity to pick up and deliver pollen to the appropriate stigma. In some studies, fewer than one-quarter of insect species visiting a particular plant proved to be competent pollinators.

As to the effects of losing the pollination services of individual species, most ecosystems depend on pollinators for food web stability. Few plant species rely on a single pollinator and many are visited by different suites of pollinator species over the course of a season. When entire suites decline, as has been the case for long-tongued bees in Europe, significant losses within the wild flora dependent upon these suites are likely. Unfortunately, missing markets make it difficult to estimate the economic value of changes to pollination services in natural communities. The economic cost of complete loss of all pollination services cannot be estimated because ecological and human adjustments to such extreme change would be radical.

One indicator of the ecological consequences of pollinator decline is pollen limitation of seed set—the failure of plants to produce the maximum number of seeds due to inadequate supplies of pollen. Pollen limitation is common in wild plants; surveys demonstrate that it is more common in plants with fewer pollinator species. In the absence of adequate pollinator populations, some plant populations, particularly those that are small, may become more vulnerable to extinction because of the elevated risks incurred by small population size, including genetic erosion, decreased reproductive success, and greater susceptibility to random catastrophic events. Because the rarest pollinator-dependent species are at greatest risk, the committee recommended that **the U.S. Geological Survey, the Fish and Wildlife Service, and other agencies responsible for natural resource protection establish discovery surveys for pollinators of rare, threatened, and endangered plant species.**

Perhaps the principal reason that estimating the ecological impact of pollinator decline is difficult is that in many natural communities pollinators are keystone species. Just as a keystone maintains the integrity of a stone arch, a keystone species maintains the integrity of an ecological community; the removal of a keystone in either case can result in a collapse of the entire structure. Identifying a keystone in a stone arch follows predictable architectural principles, but identifying a keystone species requires a vast amount of ecological information about many interacting species. Figs, for example, are considered keystone species in tropical communities around the world; in the New World tropics the fruits provide food for a broad diversity of birds, including toucans, hornbills,

parrots, and pigeons, as well as bats and monkeys and even fish in nearby rivers, the foliage supports an array of insects, including larvae of butterflies, and the tree itself provides habitat for a diversity of invertebrates, rodents, reptiles and amphibians. Fig trees, however, are entirely dependent on a group of tiny wasps that are the only known pollinators capable of negotiating the complex tangle of reproductive organs inside the fig flower; throughout the world, most fig species depend on one or sometimes two specific species of fig wasp. The entire food web, with its conspicuous, colorful, and charismatic birds, bats, and primates, thus rests on the tiny shoulders (or prothorax) of an insect averaging less than 0.1 inch in length. A cascade of ecological consequences may result from the loss or decline of a particular plant in a community, with the loss of roots, stems, leaves, flowers, fruits, and seeds that are resources for herbivores, which in turn are resources for parasites and predators.

In estimating the ecological consequences of pollinator decline, it is important to keep in mind that pollinator species play multiple roles in food webs. Most pollinating species are insects that undergo complete metamorphosis, with immature stages engaging in lifestyles bearing little or no resemblance to those exhibited by pollinating adults. Grubs, maggots and caterpillars live in different worlds, consuming entirely different foods, than do parental bees, flies, and butterflies. Moreover, pollinating adults have resource needs unrelated to the flowers they pollinate. Many require specific building materials for nests, including clay, sand, mud, bark, or plant fibers. Bumble bees often build nests in abandoned mouse burrows and some mason bees nest in beetle burrows or even vacant snail shells.

Strategies for maintaining pollinators and pollination services

Given the importance of pollinators in natural and managed communities, mitigating or reversing declines by conservation and restoration would seem advisable, but doing so effectively requires sophisticated knowledge of all aspects of pollination biology. In general, research on the basic biology and ecology of most wild pollinators is profoundly inadequate to the task at present. It is noteworthy that, while scientists today can build a spacecraft and land it with precision on a distant planet, they have yet to engineer a satisfactory replacement for any pollinator. It is evidently easier to build a craft to explore the rings and moons of Saturn than to find a flower in a prairie. The need for more research to ground conservation and restoration efforts led the committee to recommend increased funding for multidisciplinary research that promotes sustainable pollinator populations; **the National Science Foundation and USDA should recognize pollination as a cross-cutting theme in their competitive grant programs and work to integrate research that ranges from the genomics of honey bees and the systematics and ecology of wild pollinators to the effects of global climate change on pollinator-plant interactions**. On March 27, 2007, H.R. 1709 was introduced in fact with the aim of achieving many of these goals as they relate to the honey bee. While laudable (and a landmark piece of legislation) in this respect, it is important to note that the honey bee is but one of thousands of North American pollinator species and the security of America's agriculture and its natural resources depends on a healthy and diverse pollinator fauna.

Despite limits on knowledge of wild pollinators, there are many demonstrably pollinator-friendly land management practices that could, and should, be more widely implemented. Providing corridors to link habitat fragments can facilitate pollinator movement, using low- and no-till agriculture can protect nests of ground-dwelling species, and setting aside land for field margins can provide both food and shelter for pollinators. Although these practices are not at present widely used, offering economic incentives to land managers could substantially increase the rate at which they are implemented. Thus, the committee made a series of recommendations aimed at expanding incentives for pollinator conservation. Among them, **state-level Natural Resources Conservation Service**

offices should provide lists of scientifically tested and approved pollinator-friendly practices to farmers participating in USDA cost share programs (the Wildlife Habitat Incentives Program and the Environmental Quality Incentives Program) and land retirement programs (the Conservation Reserve Program, the Conservation Reserve Enhancement Program, and the Conservation Security Program. In addition, the Conservation Reserve Program should explicitly incorporate pollinator habitat in the environmental-benefits index used to evaluate land parcel proposals and in its determination of the stewardship tiers that are the basis for federal payments, and USDA cost-sharing, land retirement, and production stewardship programs should be available to producers of all commodities that depend on pollinators. On May 24, 2007, Senate Bill 1496, the Pollinator Habitat Protection Act, was introduced, adding pollinators as conservation targets for the Conservation Reserve Program, the Environmental Quality Incentives Program, and the Conservation Security Program; passage of this bill should contribute substantially toward meeting the recommendations of our committee.

Non-farm landowners, including homeowners and private businesses, also can contribute to monitoring and conserving pollinators. Federal agencies could leverage funds toward this end by encouraging partnerships among agencies, universities and nongovernmental organizations, including the North American Pollinator Protection Campaign and the Xerces Society. Citizen efforts to conserve pollinators need not be costly. For that matter, conserving pollinators may even save money; tolerating certain species regarded as weeds may have the benefit of providing resources for pollinators, and tolerating certain species regarded as pests (such as caterpillars) may pay off in increased numbers of butterflies. Raising public awareness about pollination and its importance is critical. Teaching children about actual, rather than metaphorical, birds and bees can pay tremendous dividends in reversing pollinator declines.

The interaction between flowers and pollinators has long served as an inspiration for artists and poets. The nineteenth century American poet Emily Dickinson was one such poet inspired by this mutualistic partnership. Among her numbered poems is XCVII (http://www.bartleby.com/113/2097.html):

To make a prairie it takes a clover and one bee,—
One clover, and a bee,
And revery.
The revery alone will do
If bees are few.

Unfortunately, although the sentiment is lovely, the reality is that it takes much more than revery to make a prairie—or a forest or an alpine meadow or even a desert. It takes considerably more knowledge than we currently possess about the pollinators that make most terrestrial life in North America (and the rest of the world) possible and we overlook it at our own risk.

References

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