

The Conservation of Native Bees

Elizabeth M. Bernier, *Princeton University*

Elizabeth Bernier is a 2002 graduate and was awarded the Labouisse Fellowship from Princeton University for sustainable agriculture and conservation biology research and environmental education in Puno, Peru. She plans to pursue graduate work in ecology and conservation.

Bees (Hymenoptera: Apoidea) are of substantial importance to humans—both directly and indirectly. Indirectly, we derive numerous essential resources, such as flood and erosion control, soil conservation, carbon storage, and pollination from ecosystems; these services provided by nature free of charge are called ecosystem services (Daily 1997) and are only possible due to the pollination services of bees. Bee-pollinated plants comprise a large portion of the flora in temperate, desert, and xeric regions (Michener 2000). Since these plants would not be able to reproduce without bees to pollinate them, healthy bee populations are essential for the conservation of these ecosystems upon which humans depend (Michener 2000). Furthermore, there are an estimated 250,000 flowering plant species worldwide (Buchmann and Nabhan 1996), sixty to seventy percent of which are dependent on insect pollinators (Richards 1986, Axelrod 1969) of which solitary bees, bumble bees, and honeybees are the most important (Free 1993). Therefore, bees are of direct importance to humans for two major reasons: maintaining genetic diversity in crops and crop pollination.

A large number of cultivated plants are bee-pollinated or are varieties of bee-pollinated plants (Michener 2000). Cross-pollination by bees helps maintain the genetic diversity in these species which enables horticulturalists to develop new, more productive crop varieties (Michener 2000). Secondly, the majority of fruits, vegetables, fiber and forage crops, and garden flowers are pollinated by bees (Michener 2000). The estimated value of insect-pollinated crops in the US ranged from \$4.6 to \$18.9 billion in the 1980s (Michener, 2000). According to some estimates, fifteen to thirty percent of the food consumed worldwide is dependent on pollination by bees (Burger 1981, McGregor 1976).

Pollination is a critically important and increasingly limited resource, so it behooves us to value and protect all available managed and natural pollinator populations (Delaplane and Mayer 2000). Crop pollination by bees is

attributed generally to honeybees and most estimates minimize the importance of wild bees, but these assumptions are suspect given the relative lack of data on wild bee pollinating activities (Michener 2000). Due to uneven distribution and threats to their populations, native bees may not always be dependable for commercial pollination needs (Delaplane and Mayer 2000), but honeybees (*Apis mellifera*) are not always dependable either, as described below. There is some evidence that finding enough honeybees to pollinate commercial crops is becoming increasingly difficult, in particular with California almonds,¹ avocado,² Florida citrus,³ and Washington orchard fruit (Mayer pers. obs., Delaplane and Mayer 2000).

The general disruption of pollination systems and declines of some specific pollinators worldwide due to human activities has been described as the global pollination crisis (Kremen and Ricketts 2000, Allen-Wardell *et al.* 1998, Kearns *et al.* 1998). However, a recent attempt by Williams *et al.* (2001) to document declines in the community composition and abundance of pollinators demonstrates the difficulty of generalizing the putative global pollination crisis. Three attributes of bee communities—high local diversity, large proportions of rare species, and great spatial and temporal heterogeneity—make documenting changes in abundance and composition of bee faunas particularly difficult with available data (Roubik 2001). A better understanding of the current status and population dynamics of native bees is necessary to design conservation policies that will facilitate their persistence in human-dominated landscapes (Kremen and Ricketts 2000, Delaplane and Mayer 2000, Kearns *et al.* 1998, Banaszak 1992).

A major component of the alleged pollination crisis is the reduction of managed honeybee (*Apis mellifera*) populations in the United States and Europe and wild bee populations worldwide (Allen-Wardell *et al.* 1998, Kearns *et al.* 1998, Buchmann and Nabhan 1997, Matheson *et al.* 1996). Feral honeybee colonies have also declined markedly in recent years (Delaplane and Mayer 2000). For example, in a site near Sacramento, California, the number of colonies was reduced by 75% from 1990 to 1993 (Kraus and Page 1995). The main causes of these declines are habitat degradation, fragmentation, and destruction, pesticide and insecticide use, grazing, possible competition with introduced

¹ Burnham, T. J., "California Facing Shortages of Bees for Pollination," Agricultural Alert in *The Speedy Bee*, (1994); cited in Delaplane and Mayer, (2000).

² Mussen, E., "Avocado Pollination," from the U.C. Apiaries, (Sep./Oct. 1994); cited in Delaplane and Mayer, (2000).

³ Sanford, M. T., "Shortage of Bees?" in *APIS*, 12(1), 2. University of Florida Cooperative Extension Service, (1994); cited in Delaplane and Mayer, (2000).

honeybees, infestations by two honeybee parasites (varroa and tracheal mites, *Varroa* sp. and *Acarapis woodi*, respectively) (Kremen and Ricketts 2000, Kearns *et al.* 1998). Furthermore, recent reductions in world honey prices and the spread of African honeybees into North America have made beekeeping a less attractive occupation (Delaplane and Mayer 2000). The number of beekeepers in the US declined by 20% between 1990 and 1994 (Watanabe 1994). As a result, attention is shifting increasingly from managed pollinator populations to protecting wild pollinators and elucidating their role in maintaining agricultural productivity (Kremen and Ricketts 2000, Michener 2000, Banaszak 1992, Williams 1995, Thomson 1993). Wild bees have actually been found to be better pollinators of certain crops than honeybees and a handful of species are being used commercially for this purpose (fruits trees in Japan, alfalfa, and tomatoes) (Michener 2000). In addition to their direct commercial value, wild bees provide a unique case for the application of landscape-oriented, ecosystem-based conservation policies if ecologists choose to accept the formidable challenges involved in advocating such an approach (Kearns *et al.* 1998). This approach is more sound fundamentally than other conservation policies that simply focus on rare species most of which will be protected by more integrated, landscape-based approaches (Kearns *et al.* 1998, Banaszak 1996, 1992).

The two major proximate reasons for which I did this experiment were to test the general applicability of a recent study and to investigate the smaller-scale effects of wildlands on native bee communities in Kremen's Northern California study site. Firstly, I wanted to replicate the study of Dewenter and Tschardt (1999) in Germany who found a significantly negative effect of distance from wildlands on bee abundance and diversity up to 1000 meters away from grasslands (equivalent to "wildlands" in my experiment).

Secondly, Kremen (unpublished data) observed significantly positive effects of agricultural intensification (i.e. decreasing proportion of wildlands in circular buffers around each farm) in the same general area of my experiment, though at a larger scale. She and her research team have been observing bees in watermelon fields located within the Capay Valley and in the large cropland area east of the valley in the spring and summer for several years. Kremen and her research team wanted to find out if the same pattern would apply in this site at a finer scale, especially given that this pattern—presumably an effect of agricultural intensification—on the larger landscape scale. The

Capay Valley extends from the vertical cropland/wildland interface northwest into the wildlands. Kremen analyzed her bee abundance and diversity data from a larger landscape perspective than the 1000-meter scale I used. The fields that she studied in the Capay Valley are notably different from fields outside of the Capay Valley in the large tract of cropland east of my study site. The major discernible difference is that when viewed at this larger scale, sites within the Capay Valley are surrounded by a much higher percentage of wildlands than the sites outside the valley. Therefore, scale is an important factor to keep in mind when comparing my results with those of Kremen's experiment.

My study took place in the Capay Valley which, when viewed at the larger scale at which Kremen's experiments were performed, is considered to be located entirely within the wildlands habitat (i.e. the habitat considered to be "good" for wild bees). Despite being surrounded on both sides by wildlands, the Capay Valley has an area of cropland wide enough to carry out this experiment without confounding effects of wildlands encroaching from the eastern side of the valley to within a kilometer of the transects from the western side. The purpose of my project was to examine the effect of distance from wildlands on the non-honey bee community within one kilometer of the wildland/cropland edge on the western side of the Capay Valley. (I will refer to the bee community excluding honeybees (*Apis mellifera*) as the "non-honeybee" community instead of the native bee community because there is at least one non-native bee, *Megachile apicalis*, living in the area. This species has ecological requirements similar to the native bees in the area as it nests in small holes in twigs, branches, or the ground, so lumping it with the native bee species in the area is justified.) Because not enough roads exist to facilitate access to the eastern edge of the valley extending into the expanse of cropland outside of the valley, it was not possible to perform this experiment outside of the valley. If that were possible, I would have been able to test this hypothesis over longer distances than one kilometer into the cropland.

I expected three possible outcomes to this experiment: 1) a pattern similar to the one discussed above, namely, a decline in the abundance and diversity of non-honey bees with increasing distance from wildlands, 2) a reverse effect: an increase in the abundance and diversity of non-honeybees with increasing distance from wildlands, or 3) a uniform distribution of non-honeybees with respect to distance from wildlands. My main findings were that distance from wildlands did not have a significant effect on

overall non-honey bee species diversity nor abundance, but that it did have a negative effect on the abundance of the relatively large-bodied, ground- and twig-nesting native Megachilid bees. This result suggests that either the wildland/cropland edge is more permeable than expected, or there are peculiarities about the time of season, location, experimental design, and/or landscape that make these results anomalous. As described in my introduction, there are several reasons for which this outcome may have been expected among others. The factors that might have influenced my results are the widespread availability of exotic flowering weeds, scale effects, relatively low pesticide use, and the three factors that Banaszak studied (1996): the amount of natural habitat along the edge of crop fields, the percent area covered by blooming plants, and plant species diversity. My results also suggest that the factors described that make cropland good habitat for bees (i.e. more floral resources than the wildlands available in both spring and summer) may balance the factors that likely make it inhospitable to bees (i.e. nesting limitations, feast-or-famine conditions, and pesticide use). More research is needed to determine whether this result is anomalous or whether it indicates a fundamental difference from the German grasslands where Dewenter and Tschamtkke found such strongly negative effects of distance on bee abundance and diversity.

My results indicate that the edge between wildlands and croplands in this study site may not be as impermeable to bees as expected due to results from other studies in intensive agricultural areas. These results have important implications for landscape-based conservation efforts and restoration projects designed to bolster bee populations for conservation and/or pollination services. These issues are particularly topical given the recent declines in some bee populations due to anthropogenic activity and our dependence on bee pollination for a third of our food supply.

An encouraging aspect of my results is that the study was done entirely in what Kremen refers to as the "good" habitat for native bees. The finding that bees, except for *Megachile sp.*, were distributed uniformly across the landscape may be an indication of what restoration ecology or managing the landscape for bees could achieve, for example, outside the Capay Valley where bee species diversity and abundance appear to fall off more sharply than inside the valley with increasing agricultural intensity. Maybe the neutrality of species diversity and abundance of bees means that this cropland area is hospitable to bees despite agricultural activity. In order to corroborate this conclusion, one would

need to compare past and present records of bee populations to determine how the community has changed. Comparisons with records in nearby wildlands may be able to provide a surrogate, albeit imperfect, record of the pre-irrigated agriculture bee community. Alternatively, these results could indicate that the entire bee community in the valley is depauperate and, therefore, the uniform distribution of species and abundance is an indication of a degraded community. A study conducted in British Columbia suggests that bee abundance and diversity are generally lower in disturbed agricultural areas as compared to natural vegetation (MacKenzie and Winston 1984). Collecting more data over time and comparing current findings with past records, if available, would help distinguish between these interpretations.

Furthermore, my results seem to indicate that both the croplands and wildlands are suitable habitat for foraging and possibly for nesting to many native bees in the area. Kevan (1999) explains that the species diversity and robustness of bee populations can serve as bioindicators of the state of a local environment. Surveys like this experiment that assess the status of bee populations using a standard indicator (sunflower arrays arranged uniformly with respect to a particular feature of the landscape) could be used to monitor farming practices—the robustness of the bee population being an indicator of proper management practices. If they are sensitive to pesticides, then surveying the bee community could be used to monitor importance of the pesticide and wildlands effects on bee communities in order to prioritize future conservation efforts. Indeed, more research is needed to determine more clearly whether or not bees are susceptible to pesticides and to determine their relative sensitivities.

In order to maintain bee populations, Banaszak recommends that cultivated land be limited to three-quarters of the total area in an agricultural landscape, leaving the remaining 25% as a habitat for bees (1992). Delaplane and Mayer (2000) also argue that maintaining large, continuous sanctuaries, ideally on a larger scale than that of individual farms, are the best way to conserve bee populations. Williams *et al.* (1991) hypothesize that the large monoculture fields typical of conventional fields of flowering crops may be so attractive to bees that they leave native plants without pollinators, thereby exacerbating their decline. Clearly, more research needs to be done on these effects of croplands on wildlands. Large, conventional monoculture farm fields appear to be problematic for many reasons in addition to their potential negative effect on native bee populations, including the high levels of pesticide, insecticide,

and fertilizer use and mechanization that they require, negative aesthetic value, soil loss caused by excessive tilling, use of genetically modified crops, and their inhospitability to many organisms—including the people who work in them. Converting these farms to smaller organic farms could be an excellent way both to preserve natural habitat for bees and other native organisms while providing pollination services for crops and avoiding some of the other problems associated with conventional farming. Diverting some subsidies for large agribusiness towards relatively small, organic farms would be an important first step towards a more sustainable system of food production. Bee conservation could play an important part of agricultural land use policy (Delaplane and Mayer 2000) that would also help protect native vegetation and wildlife. Indeed, native bees may be an umbrella species (i.e. a species whose preservation leads to the preservation of numerous other species due to overlapping habitat or other resource requirements) with the added advantage of having a direct economic importance, unlike some other umbrella species (e.g. top predators).

Bibliography

- Allen-Wardell, G., P. Bernhardt, R. Bitner, A. Burquez, S. Buchmann, J. Cane, P.A. Cox, V. Dalton, P. Feinsinger, M. Ingram, D. Inouye, C.E. Jones, K. Kennedy, P. Kevan, H. Koopowitz, R. Medellin-Morales, G.P. Nabhan. 1998. "The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields," in *Conservation Biology* 12: 8-17.
- Axelrod, D. I., "The evolution of flowering plants" in Sol Tax, ed., *Evolution after Darwin. Volume 1. The evolution of life.* (Chicago: University of Chicago Press, 1969), pp. 227-305.
- Banaszak, J. 1992. "Strategy for conservation of wild bees in an agricultural landscape," *Agriculture, Ecosystems and Environment* 40: 179-192.
- _____, "Ecological bases of conservation of wild bees" in A. Matheson, S.L. Buchmann, C. O'Toole, P. Westrich, and I.H. Williams, eds., *The Conservation of Bees.* (New York: Academic Press, 1996).
- Buchmann, Stephen L. and Gary Paul Nabhan, *The Forgotten Pollinators.* (Washington, D.C.: Island Press for Shearwater Books, 1996).
- Burger, W.C. 1981. "Why Are There So Many Kinds of Flowering Plants?" *Bioscience* 31: 572-581.
- Daily, Gretchen C., ed., *Nature's Services: Societal Dependence on Natural Ecosystems.* (Washington, DC: Island Press, 1997).
- Delaplane, Keith S. and Daniel F. Mayer, *Crop Pollination by Bees.* (Wallingford, England: CABI, 2000).
- Free, John Brand, *Insect Pollination of Crops*, 2nd ed. (London: Academic Press, 1993).
- Kearns, C.A., D.W. Inouye, and W.M. Waser. 1998. "Endangered Mutualisms: The Conservation of Plant-Pollinator Interactions" in *Annual Review of Entomological Systems* 29: 83-112.
- Kevan, P.G. 1999. "Pollinators as bioindicators of the state of the environment: species, activity, and diversity" in *Agricultural Ecosystems and Environment* 74: 373-393.
- Kraus, B. and R.E. Page Jr. 1995. "Effect of *Varroa jacobsoni* (Mesostigmata: Varroidae) on feral *Apis mellifera* (Hymenoptera: Apidae) in California" in *Environmental Entomology* 24: 1473-1480.
- Kremen, C. Unpublished Data. Spring 2002. Assistant Professor of Ecology and Evolutionary Biology jointly appointed by the Princeton Environmental Institute. Princeton: Princeton University.
- Kremen, C. and T. Ricketts. 2000. "Global Perspectives on Global Pollination Disruptions" in *Conservation Biology* 14 (5): 1226-1228.
- MacKenzie, K.E. and M.L. Winston. 1984. "Diversity and abundance of native bee pollinators on berry crops and natural vegetation in the lower Fraser Valley, British Columbia" in *Canadian Entomologist* 116: 965-974.
- Matheson, A., S.L. Buchmann, C. O'Toole, P. Westrich, and I.H. Williams, *The Conservation of Bees.* (New York: Academic Press, 1996).
- McGregor, Samuel Emmett, *Insect Pollination of Cultivated Crop Plants.* (Washington, D.C.: Agricultural Research Service, U.S. Dept. of Agriculture, 1976).
- Michener, Charles Duncan, *The Bees of the World.* (Baltimore: Johns Hopkins University Press, 2000).
- Richards, A. J., *Plant breeding systems.* (New York: Chapman and Hall, 1986).
- Roubik, David W., and Wolda, H., "Do competing honey bees matter? Dynamics and abundance of native bees before and after a honey bee invasion," in *Population Ecology*, vol. 43, no. 1, (2001), pp. 0053-0062.
- Roubik, David W., "Ups and downs in pollinator populations: When is there a decline?" in *Conservation Ecology* (online) URL: <http://www.consecol.org/vol2/iss1/art2>

- Steffan-Dewenter, I. and T. Tscharnkte. 2000. "Resource overlap and possible competition between honey bees and wild bees in central Europe" in *Oecologia* 122: 288-296.
- Thomson, J.D. 1993. "The Queen of Forage and the Bumblebee Revolution: A Conference with an Attitude" in *Trends in Ecology and Evolution* 8 (2): 41-42.
- Watanabe, M.E. 1994. "Pollination worries rise as honey bees decline" in *Science* 265: 1170.
- Williams, C.S. 1995. "Conserving Europe's bees: why all the buzz?" in *Trends in Ecology and Evolution* 10: 309-310.
- Williams, N. M., R. L. Minckley, and F. A. Silveira. 2001. "Variation in native bee faunas and its implications for detecting community changes" in *Conservation Ecology* 5 (1): 7. [<http://www.consecol.org/vol5/iss1/art7>]
- Williams, I.H., N. Carreck, and D.J. Little. 1991. "Beekeeping, wild bees and pollination in the European Community" *Bee World* 72: 170-180.