The Role of Native Bees in Apple Pollination

Andrena crataegi. Photo: Phil Huntley-Franck

Mia G. Park, Michael C. Orr, & Bryan N. Danforth
Department of Entomology
Comstock Hall
Cornell University, Ithaca, NY

> **"Our bee survey revealed that there is an impressive diversity of native bee species in the NY orchards we surveyed. Our surveys suggest that native bees are very abundant in apple orchards and a number of native bees we found, such as *Andrena, Osmia* and *Bombus* are reported to be effective vectors of apple pollen."**

Pollination is an essential step in production of fruits and many vegetables. The most widely used insect for fruit pollination is the European honey bee, *Apis mellifera*. Honey bees are ideal pollinators in many crop systems: each colony produces thousands of foraging workers and colonies can be moved into orchards and fields during the flowering period. They are especially important pollinators in large-scale, highly disturbed agroecosystems (the Central Valley of California, for example). However, honey bee populations in North America (NA) and Europe are in decline (Aizen & Harder 2009), primarily due to heavy pathogen and parasite loads (Ratnieks & Carreck 2010). Problems of honey bee health became particularly acute in 2007/2008 when many colonies across N. America experienced colony collapse disorder (CCD). There is most likely no single pathogen involved in CCD (Oldroyd 2007, Ratnieks & Carreck 2010). It appears more and more likely that a *combination* of pathogens and stresses (e.g., pesticide exposure, long-distance transportation associated with migratory beekeeping) are involved. It is also important to keep in mind that honey bees are not native to NA; they were introduced in the 1600s by early European colonists.

While honey bees are important, they are certainly not the only crop pollinators (National Research Council of the National Academies 2006). Native bees (species of bees that are native to NA) play an important, but underappreciated, role in crop pollination. Bees are an enormously diverse group. There are over 20,000 species of bees in the world (Michener 2007), approximately 4000 species in NA, and approximately 450 species in New York State (NY) alone. One potential solution to the decline in honey bee populations in NA is to examine the role that native bees are playing in crop pollination and to develop management practices that promote and maintain healthy native bee populations in and around agricultural areas. A number of recent studies in agricultural systems have suggested that native bees play an important role in crop pollination (Kremen et al. 2002; Winfree et al. 2007). However, we are just beginning to understand the conditions under which native bees may play an important role.

Apples are an important crop in NY. New York State is the second largest producer of apples in the United States with an average of 25 million bushels of apples produced annually by a total of approximately 694 commercial growers and annual sales reaching $261 million (USDA NASS, 2008; http://www.nass.usda.gov/). There are an estimated 17,000 people who work in the handling, distribution, marketing, processing and shipping of apples in NY. Bountiful apple harvests would not exist if it were not for bee pollinators. In 2008, we began a project to investigate the abundance and diversity of native bees in apple orchards in NY. Our goal was to determine if native bees provide a viable alternative to honey bees in apple pollination and to provide growers with advice on how to maintain native bee diversity and abundance. Specifically, our project has two main goals: (1) assess grower awareness and perceptions regarding pollination services provided by native bees and (2) survey bee diversity and abundance in apple orchards of various size and management regime.

Methods

Grower survey In May 2009 we conducted a survey of the approximately 690 commercial apple growers in NY with the help of the National Agricultural Statistics Service, New York Field Office. Our survey included 24 questions related to grower practices and perceptions about native bees as pollinators. An initial survey was conducted by mail with additional respondents contacted by phone. A total of 262 growers in 43 counties responded to all or part of the survey. The survey included statistics on the size of the orchard, the management practices used (conventional, IPM, or organic), and the number of apple varieties grown. This initial survey of NY apple growers provides baseline information on current management practices, perceptions about the importance of native bees in apple pollination, and willingness to adopt practices that would enhance wild bee pollination in apple orchards.

Bee survey At the same time (May 2009), we conducted biodiversity surveys of native bees in 11 orchards in the vicinity of Ithaca, NY. On warm (>60ºF), sunny days between 10am and 2pm we netted bees visiting apple blossoms using the following two methods: (1) "General collecting" consisted of walking along rows of apple trees and netting any native bees we observed landing on or flying around apple blossoms. We did not collect honey bees during this type of survey. Our goal was to characterize the *diversity* of native bee species present in each orchard. (2) "Time-trial collecting" consisted of collecting all bees (honey bees and native bees) during 15-minute intervals. For 15 minutes we walked down a row of apple trees and collected any bees observed. The 15-minute timed collections gave us information on bee abundance (numbers of individuals of different species) per unit time. These collections allowed us to compare both overall bee abundance as well as the relative abundance of native vs. honey bees.

In both "general collecting" and "time-trial collecting", bees were killed in cyanide killing jars, stored in labeled collecting vials, and later mounted on insect pins. Specimens were labeled with a unique barcoded label and subsequently entered into a relational database (Biota 2.04; Colwell 2006). Specimens were then determined to species using available taxonomic literature as well as comparison to authoritatively identified specimens in the Cornell University Insect Collection (http://www2.entomology.cornell.edu/public/IthacaCampus/CUIC.html).

Results

Grower survey Two hundred sixty-two growers responded to the survey from over 43 counties. Growers surveyed provided a spatially representative sample of NY as shown by comparing percent apple growers by county from 2009 census data and percent respondents by county (Table 1). Growers employed a variety of pest management regimes, with the majority using Integrated Pest Management (IPM) (Figure 1). In terms of acres in production, respondents also represented state averages.

For pollination, grower reliance on honey bee rentals depended on farm size. Among growers with more than 100 acres in apple production, 96% always rented honey bees for pollination. Conversely, in apple orchards with under 10 acres, 73% of growers never rented honey bees (Figure 2). But this did not consider people who keep their own bees. Considering larger farms rent more bees, it is not surprising that the proportion of growers who deemed honey bee rentals to be a major expense increased also with farm size (Figure 3). Sixty percent of growers with less than 50 acres of apple production had at one time considered relying exclusively on wild bees, but the same proportion of growers, 63%, with over 100 acres had not (Figure 4).

Concern over reliable pollination and support for the importance of wild apple pollinators were both high. Recent declines in honey bee populations due to CCD were considered a threat to successful apple production by 59% of NY apple growers. Native bees were viewed by 85% of surveyed growers as valuable pollinators. In spite of widespread appreciation for native pollinators, however, knowledge of the biology and diversity of wild bees was low. About 75% of NY apple growers said there were 10 or fewer wild bee species that visit apple. In our first year of field surveys, we identified over 80 species of bees in the 11 orchards studied (see below). Whether all 80 are important pollinators remains to be determined, but many species look identical to the untrained eye. Little to no extension information is available to growers about native pollinators in apple. This is unsurprising since the research community has only recently begun to examine the diversity and abundance of non-honey bees in agricultural settings.

Willingness on the part of growers to enhance native pollinators was also high. Sixty-eight percent of NY apple growers said they would consider adopting low-cost land management practices to increase the diversity and abundance of bees in their orchards. The top criteria for doing so included cost, effectiveness, effort, and insurance that practices did not harm honey bees. Already, 93% growers consider impacts on pollinators when using chemical treatments. Thirty percent of NY apple growers were familiar with alternative managed apple pollinators (such as the mason bee), but only 2% have ever used them. This reflects a gap on the east coast for alternatives to managed honey bees. Even though *Osmia lignaria* (Blue orchard bee) is widely used in orchards on the West Coast, *Osmia* bees are not naturally common in NY orchards, nor are they commercially available and do not perform as well on the East Coast (Ray Williams, pers. comm.).

Throughout NY, there seems to be overwhelming support for the importance of wild pollinators and a willingness to make low-cost changes that will enhancing their populations. This comes from growers who practice both conventional, organic and IPM. IPM has been adopted by most NY apple growers. As it aims to control pests with multiple tactics to minimize harm to humans, animals, plants and the environment, IPM could provide a framework within which pollinator conservation may be incorporated. IPM also provides an existing infrastructure in which to develop extension support for

Table 1: Relationship between percentage of responses by county and the proportion of apple growers by county for the top 9 counties.

County	% responses	% censused
Wayne	20.2	16.4
Ulster	10.3	5.7
Orleans	8.8	6.1
Niagara	6.5	6
Columbia	5	4.1
Monroe	3.8	3.1
Dutchess	2.7	2.4
Onondaga	2.7	2.2
Orange	2.3	1.3

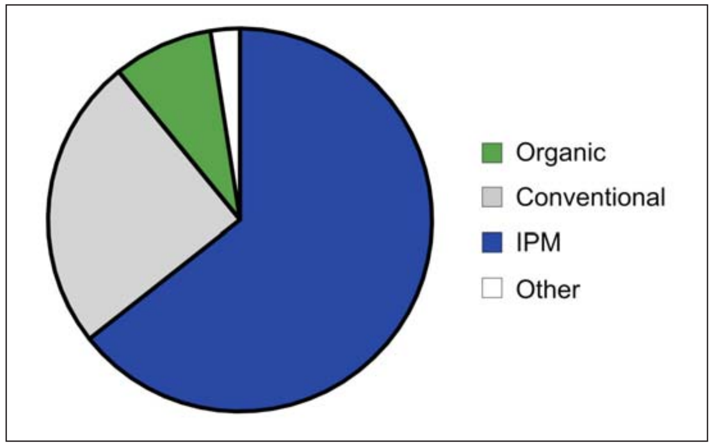

Figure 1: Pie chart showing the relative proportion of growers surveyed utilizing conventional, IPM, and organic management practices.

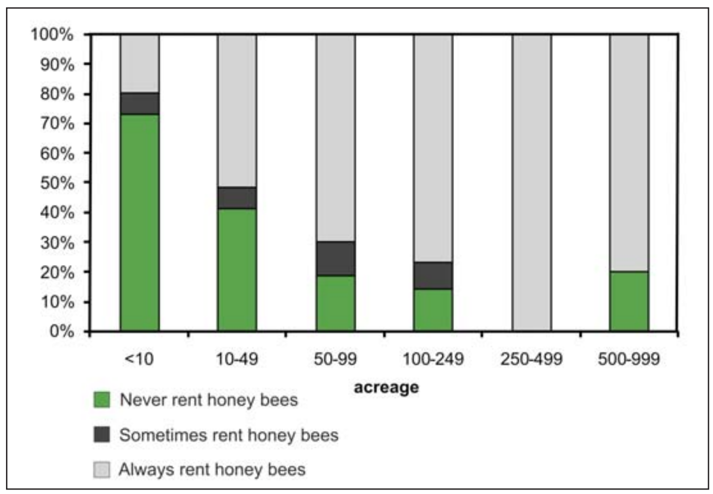

Figure 2: Percent growers that rent honey bees for pollination and total apple acreage owned.

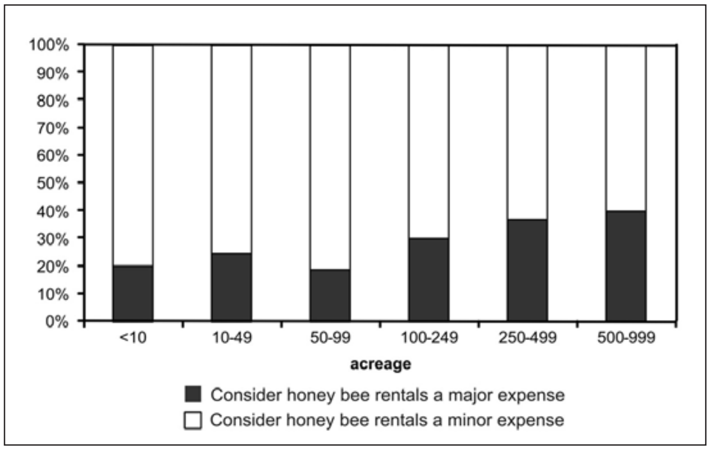

Figure 3: Percent growers that considered honey bee rentals a major expense and total apple acreage owned.

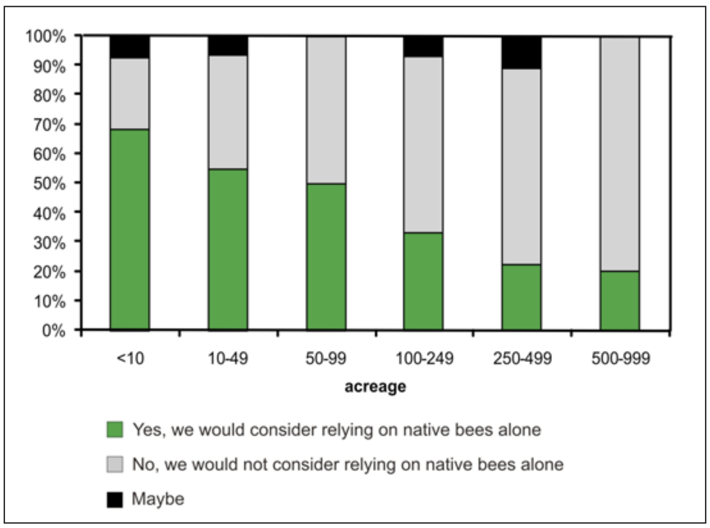

Figure 4: Percent growers who have considered relying on native bees and acres in apple production.

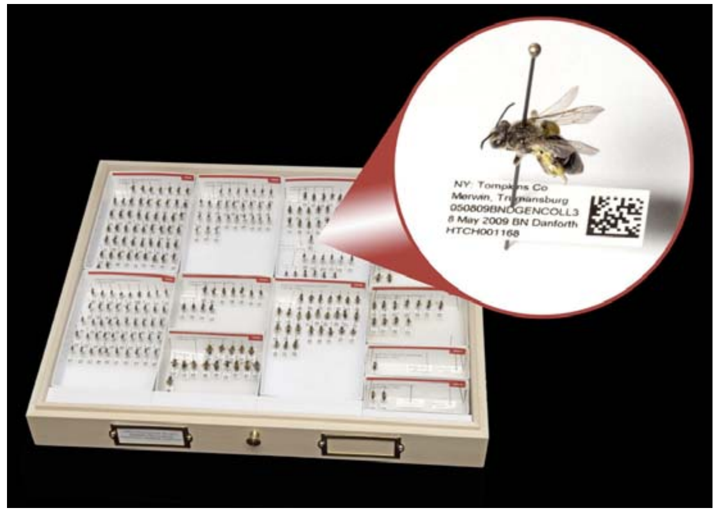

Figure 5: Mounted, individually labeled, and identified specimens sorted to species; individual specimen showing unique barcode label [insert].

pollinator enhancement. For both grower use of honey bee rentals and consideration to rely on wild pollinators alone, we observed a farm size threshold somewhere between 50-100 acres. This would be interesting to test experimentally. On one hand, growers with 100 acres or more may rely exclusively on apple production for their income and would never risk going without honey bees. On the other hand, native bees might be less effective in larger orchards; we simply don't know how orchard size impacts native bee communities. Managed alternative pollinators and information about wild pollinators are currently not readily available or well developed for apple growers on the east coast.

Bee survey Our bee survey revealed that there is an impressive diversity of bee species in the 11 orchards surveyed. Over three-weeks, we collected over 3000 specimens, which have now been individually labeled, identified to species, and entered into our Biota database (Figure 5). Our survey revealed a total of 81 species of bees visiting apple blossom during the bloom period (Table 2). This is twice the number of bee species collected in an earlier study in the same area of NY (Gardner & Ascher 2006) and roughly 8 times the number of species estimated by the growers we surveyed (see above). Many of these species appear to be important apple pollinators, especially members of the genera *Andrena*, *Osmia*, and *Bombus*. Across the orchards sampled, native bees consistently outnumbered honey bees on an individual (i.e., per-bee) basis.

There was substantial variation among orchards in both the number of bee species and the abundance of individual bees. While some orchards had as few as 15 bee species, others had as many as 42 species. The number of bee species was positively correlated with orchard size, while the abundance of native bees (based on the 15-minute samples) declined with orchard size. We plan to examine the interaction between orchard size and both native bee diversity and abundance in coming years. In terms of numerical abundance of individual bees, native bee were more abundant than honey bees in 9 of the 11 sampled orchards (Figure 6), suggesting that native bees are playing an important role in apple pollination. We plan to explore these trends in future years by surveying over a larger range of orchard sizes. Interestingly, there was a slight (but non-significant) negative correlation between native bee abundance and honey bee abundance, suggesting that competition between native and honey bees may be an important determinant of the orchard bee fauna. At one commercially producing orchard (West Haven Farm) honey bees were apparently absent, indicating that sufficient pollination services were provided by native bees alone (Figure 6).

Overall, our first year of surveying bees has yielded exciting insights into the potential importance of native bees in agricultural pollination of apples. Numerically, our surveys suggest that native bees are very abundant in apple orchards and a number of previous studies have suggested that native bees, such as *Andrena* (Kendall 1973, Kendall & Solomon 1973), *Osmia* (Bosch & Kemp 2001) and *Bombus* (Thomson & Goodell 2001) are effective vectors of apple pollen.

Acknowledgments

We are extremely grateful to the growers who allowed us to conduct bee surveys in their orchards: Brian Caldwell (Hemlock Grove Farm), John Bokaer-Smith (West Haven Farm), Renie Sandstead (Baker's Acres), Richard Reisinger (Reisinger's Apple Country), Steve Cummins and Alan Leonard (Indian Creek Farm), Susan Grisamore (Grisamore Farms), Dennis Hartley (Littletree

Table 2: List of 80 bee species (organized by family) collected in our surveys.

Genus (subgenus) species	Author	Family
Andrena (Andrena) mandibularis	Robertson, 1892	Andrenidae
Andrena (Andrena) milwaukeensis	LaBerge 1980	Andrenidae
Andrena (Andrena) rufosignata	Cockerell, 1902	Andrenidae
Andrena (Andrena) thaspii	Graenicher, 1903	Andrenidae
Andrena (Euandrena) algida	Smith, 1853	Andrenidae
Andrena (Gonandrena) integra	Smith, 1853	Andrenidae
Andrena (Holandrena) cressonii	LaBerge 1986	Andrenidae
Andrena (Larandrena) miserabilis	Ribble 1967	Andrenidae
Andrena (Leucandrena) barbilabris	LaBerge, 1987	Andrenidae
Andrena (Leucandrena) erythronii	Robertson, 1891	Andrenidae
Andrena (Melandrena) carlini	Cockerell, 1901	Andrenidae
Andrena (Melandrena) commoda	Smith, 1879	Andrenidae
Andrena (Melandrena) dunningi	Cockerell, 1898	Andrenidae
Andrena (Melandrena) nivalis	Smith, 1853	Andrenidae
Andrena (Melandrena) pruni	Robertson, 1891	Andrenidae
Andrena (Melandrena) regularis	Malloch, 1917	Andrenidae
Andrena (Melandrena) vicina	Smith, 1853	Andrenidae
Andrena (Plastandrena) crataegi	Robertson, 1893	Andrenidae
Andrena (Ptilandrena) erigeniae	Robertson, 1891	Andrenidae
Andrena (Scrapteropsis) imitatrix	LaBerge 1971	Andrenidae
Andrena (Scrapteropsis) morrisonella	Viereck, 1917	Andrenidae
Andrena (Simandrena) nasonii	LaBerge 1989	Andrenidae
Andrena (Thysandrena) bisalicis	LaBerge 1977	Andrenidae
Andrena (Trachandrena) forbesii	LaBerge 1973	Andrenidae
Andrena (Trachandrena) hippotes	LaBerge 1973	Andrenidae
Andrena (Trachandrena) nuda	LaBerge 1973	Andrenidae
Andrena (Trachandrena) rugosa	LaBerge 1973	Andrenidae
Andrena (Tylandrena) perplexa	Smith, 1853	Andrenidae
Apis mellifera	Linnaeus, 1758	Apidae
Bombus bimaculatus	Cresson, 1863	Apidae
Bombus griseocollis	(DeGeer, 1773)	Apidae
Bombus impatiens	Cresson, 1863	Apidae
Bombus perplexus	Cresson, 1863	Apidae
Bombus ternarius	Say, 1837	Apidae
Bombus vagans	Smith, 1854	Apidae
Ceratina calcarata	Robertson, 1900	Apidae
Ceratina dupla	Say, 1837	Apidae
Nomada ceanothi	Cockerell, 1907	Apidae
Nomada dreisbachi	Mitchell, 1962	Apidae
Nomada gracilis	Cresson, 1863	Apidae
Nomada pygmaea	Cresson, 1863	Apidae
Xylocopa virginica	(Linnaeus, 1771)	Apidae
Colletes inaequalis	Say, 1837	Colletidae
Agapostemon sericeus	(Forster, 1771)	Halictidae
Augochlora pura	(Say, 1837)	Halictidae
Augochlorella aurata	(Smith, 1853)	Halictidae
Augochloropsis metallica	(Fabricius, 1793)	Halictidae
Halictus (Halictus) ligatus	Say, 1837	Halictidae
Halictus (Halictus) rubicundus	(Christ, 1791)	Halictidae
Halictus (Seladonia) confusus	Smith, 1853	Halictidae
Lasioglossum (Dialictus) atlanticum	(Mitchell, 1960)	Halictidae
Lasioglossum (Dialictus) coeruleum	(Robertson, 1893)	Halictidae
Lasioglossum (Dialictus) cressonii	(Robertson, 1890)	Halictidae
Lasioglossum (Dialictus) foxii	(Robertson, 1895)	Halictidae
Lasioglossum (Dialictus) imitatum	(Smith, 1853)	Halictidae
Lasioglossum (Dialictus) laevissimum	(Smith, 1853)	Halictidae
Lasioglossum (Dialictus) lineatulum	(Crawford, 1906)	Halictidae
Lasioglossum (Dialictus) obscurum	(Robertson, 1892)	Halictidae
Lasioglossum (Dialictus) paradmirandum	(Knerer & Atwood, 1966)	Halictidae
Lasioglossum (Dialictus) perpunctatum	(Ellis, 1913)	Halictidae
Lasioglossum (Dialictus) pilosum	(Smith, 1853)	Halictidae
Lasioglossum (Dialictus) subviridatum	(Cockerell, 1938)	Halictidae
Lasioglossum (Dialictus) versans	(Lovell, 1905)	Halictidae
Lasioglossum (Dialictus) versatum	(Robertson, 1902)	Halictidae
Lasioglossum (Dialictus) viridatum	(Lovell, 1905)	Halictidae
Lasioglossum (Dialictus) zephyrum	(Smith, 1853)	Halictidae
Lasioglossum (Evylaeus) cinctipes	(Provancher, 1888)	Halictidae
Lasioglossum (Evylaeus) quebecense	(Crawford, 1907)	Halictidae
Lasioglossum (Evylaeus) truncatum	(Robertson, 1901)	Halictidae
Lasioglossum (Lasio.) leucozonium	(Schrank, 1781)	Halictidae
Sphecodes cressonii	(Robertson, 1903)	Halictidae
Sphecodes dichrous	Smith, 1853	Halictidae
Osmia albiventris	Cresson, 1864	Megachilidae
Osmia bucephala	Cresson, 1864	Megachilidae
Osmia collinsiae	Robertson, 1905	Megachilidae
Osmia cornifrons	(Radoszkowski, 1887)	Megachilidae
Osmia lignaria	Say, 1837	Megachilidae
Osmia pumila	Cresson, 1864	Megachilidae
Osmia subfasciata	Cresson, 1872	Megachilidae
Osmia taurus	Smith, 1873	Megachilidae

Orchards), Hugh Ink (Cornell Orchards, Ithaca and Lansing), Ian Merwin (Black Diamond Farm), and Richard Endres (Fruition Farm). We are grateful to Steve Ropel and Marisa Reuber (USDA, National Agricultural Statistics Service, Albany NY) for implementation and analysis of the grower survey. Yasamin Miller (Cornell Survey Research Institute, Cornell University, Ithaca, NY) provided additional assistance with the analysis of survey data. We are also grateful to Ian Merwin and Art Agnello for advice on apple orchard management and Julie Carroll for advice on IPM practices in apple orchards. Lori Moshman, Margarita López-Uribe, Jesse Litman, and Sophie Cardinal helped with surveys of apple bee diversity. Robert Minckley (University of Rochester) provided essential guidance on developing the Biota database and associated barcoding software. This project was supported in part by Smith Lever Funds administered by Cornell Cooperative Extension and Hatch Funds administered by the Cornell University Agricultural Experiment Station.

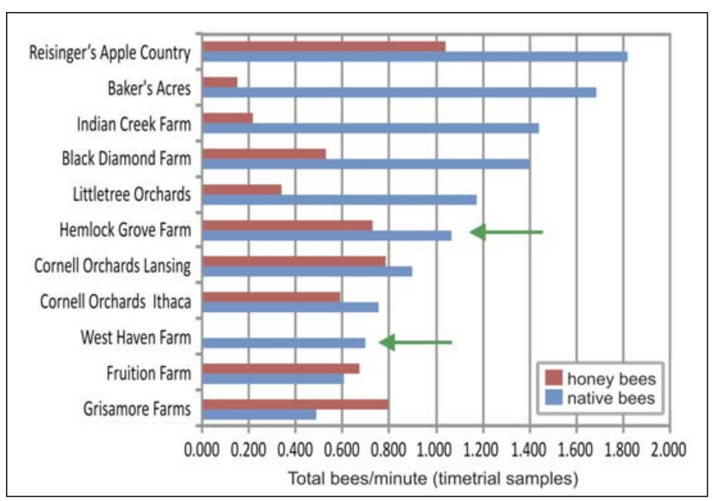

Figure 6: Relative abundance of native and honey bees in 11 apple orchards (red bar: honey bees; blue bar; native bees). Orchards indicated by the green arrow are organic.

References cited

Aizen, M.A. & L.D. Harder (2009). The global stock of domesticated honey bees is growing slower than agricultural demand for pollination. *Current Biology* 19:1-4.

Bosch, J. & W. Kemp (2001). How to manage the blue orchard bee : as an orchard pollinator. Beltsville, MD : Sustainable Agriculture Network.

Colwell, R. K. (2006). *Biota: The biodiversity database manager, Version 2*. Sinauer Associates, Sunderland, MA.

Gardner, K.E. & J.S. Ascher (2006). Notes on the native bee pollinators in New York apple orchards. *J. New York Entomol. Soc*. 114: 86-91.

Kendall, D.A. (1973) Viability and compatibility of pollen on insects visiting apple blossom. *Journal of Applied Ecology*, 10, 847–853.

Kendall, D.A. & M.E. Solomon (1973) Quantities of pollen on bodies of insects visiting apple blossom. *Journal of Applied Ecology*, 10, 627–634.

Klein, A.M., B. Vaissiére, J.H. Ca ne, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen, et al. (2007). Importance of crop pollinators in changing landscapes for world crops. Proc. R. Soc. Lond. B, *Biol. Sci*. 274: 303–313.

Kremen, C., N.M. Williams, & R.W. Thorp (2002). Crop pollination from native bees at risk from agricultural intensification. *Proc. Natl Acad. Sci.* USA. 99: 16812–16816.

Michener, C.D. (2007). *Bees of the World*. Johns Hopkins Press, Baltimore, MD.

National Research Council of the National Academies (2006). Status of Pollinators in North America. National Academy Press, Washington, DC.

Oldroyd, B.P. (2007). What's killing American honey bees. *PloS Biol* 5(6): e168.doi:10.137/*journal.pbio*.0050168.

Ratnieks, F.L.W. & N.L. Carreck (2010). Clarity on honey bee collapse? *Science* 327: 152-153.

Thomson, J. D., & K. Goodell. (2001). Pollen removal and deposition by honey bee and bumblebee visitors to apple and almond flowers. *Journal of Applied Ecology*. 38: 1032-1044.

Winfree, R. N.M. Williams, J. Duschoff & C. Krem en (2007). Native bees provide insurance against ongoing honey bee losses. *Ecology Letters* 10:1105-1113.

Mia Park is a PhD student in the Dept. of Entomology (Ithaca), Cornell University studying the role of native bees in apple pollination. **Michael C. Orr** is an undergraduate major in Entomology. **Bryan Danforth** is a professor in the Dept. of Entomology (Ithaca) who specializes on bee diversity and evolution.