CONSERVATION

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Reviving native bee species could save honeybees—and

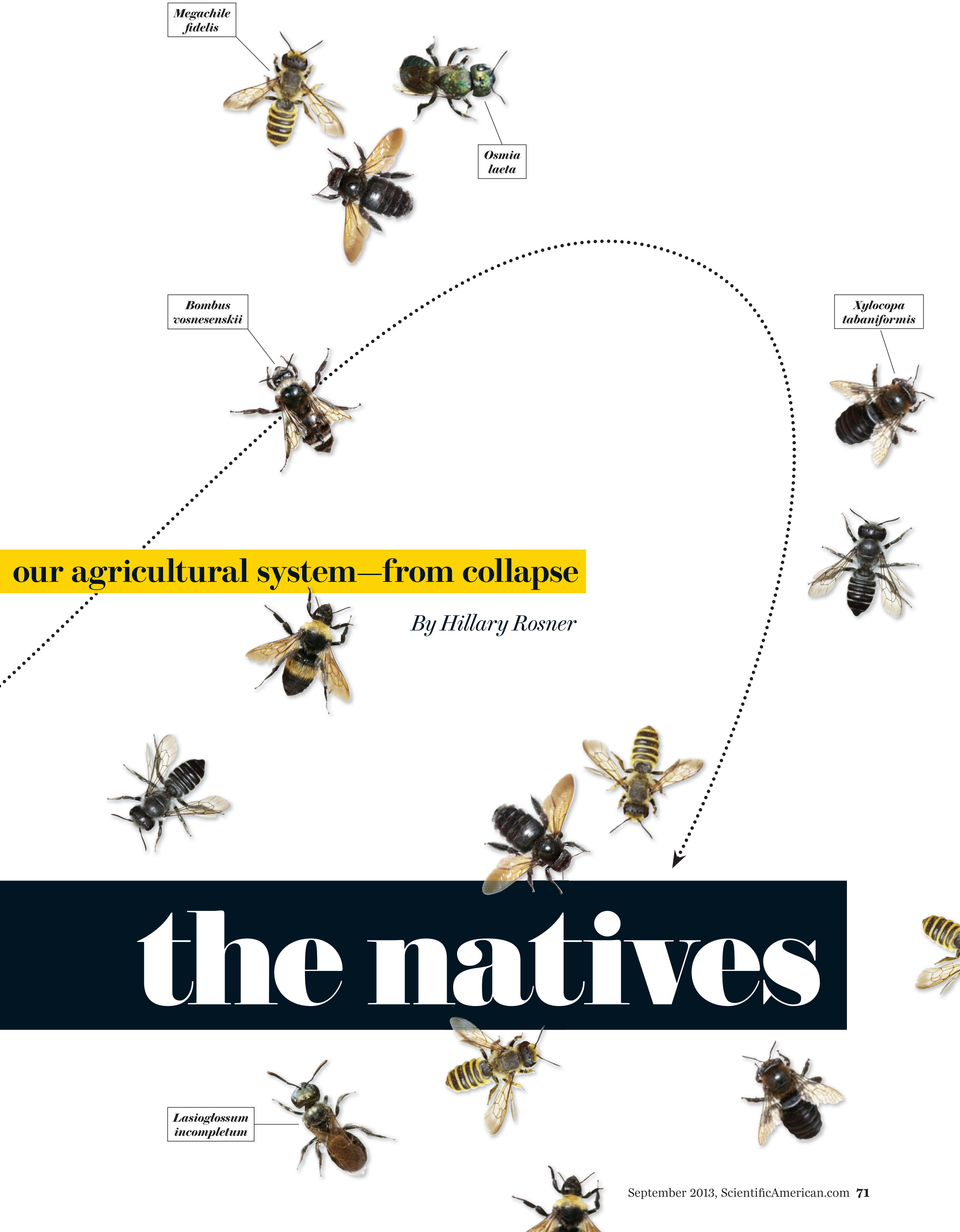
IN BRIEF

The U.S. relies primarily on a single insect, the domesticated European honeybee, to pollinate one third of its food supply, including such delicious crops as apples, peaches, almonds, lettuces, broccoli, cranberries, squashes, melons and blueberries.

As colony collapse disorder and other maladies continue to devastate honeybee populations, researchers are turning their attention to alternative pollinators—the thousands of native bee species throughout the country—and are looking for ways to make croplands more attractive to these wild bees.

So far studies suggest that restoring wild habitat near farms to welcome and nurture native bees not only increases crop yield but also makes honeybees themselves more efficient pollinators.

Photographs by David Liittschwager



our agricultural system—from collapse

the natives

By Hillary Rosner

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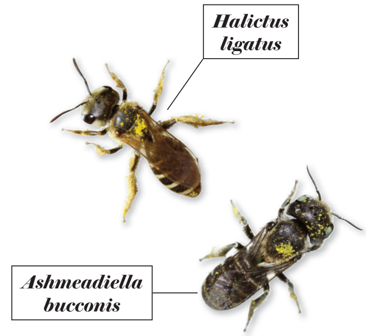

FIELD BIOLOGISTS HAVE A STRANGE AFFINITY for spending countless hours in the hot sun scrutinizing tiny things. You might see a bee buzzing on a flower and think, "Oh, a bee." A biologist, though, will want to know: Is it a nonnative, domesticated honeybee? Or is it one of 4,000 bee species native to the U.S.—maybe an ultragreen sweat bee, a metallic-sheened creature that drinks human perspiration? Or perhaps a cuckoo bee, such as *Bombus suckleyi,* a type of bumblebee that sports yellow hair on its fourth abdominal segment, as opposed to the rare *B. occidentalis,* which has black or white hair in the same spot?

You also can probably name many reasons not to sit in a field counting grains of pollen, an activity that conservation biologist Claire Kremen thinks is a perfectly reasonable way to spend an afternoon. But then, you probably will not be the one to revamp the nation's food supply and rescue our agricultural system from looming collapse. Kremen, however, just might.

A decade ago, after years of work in Madagascar, she turned her attention to a problem brewing closer to home. Colony collapse disorder (CCD) had not yet been diagnosed or named, but already American beekeepers were reporting record deaths within their honeybee hives. A third of the U.S. food supply depends primarily on the honeybee for pollination—apples, almonds, peaches, lettuces, squashes, melons, berries and broccoli, to name a few crops. Kremen, now at the University of California, Berkeley, began to wonder about other kinds of bees. Could wild native bee species ease our dependence on honeybees by lessening their workload?

With Neal Williams, at the time a graduate student in her then Princeton University laboratory, and Robbin Thorp, a renowned bee taxonomist, Kremen studied watermelon pollination in California's Central Valley. Kremen and her team monitored how frequently each of 39 different bee species visited a flower and how much pollen each bee deposited. Based on previous studies, they knew that it takes around 1,000 grains of pollen to build a single juicy watermelon. Growers on organic farms surrounded by wild plants, it turned out, did not even bother hiring hives. The native bees did all the work, saving the farmers money year after year. In contrast, on conventional monoculture farms with large swaths of a single crop the wild bees barely made a dent. Without honeybees, those farmers would be looking for new jobs.

The resulting paper, published in 2002 in the *Proceedings of the National Academy of Sciences USA,* concluded that by restoring native bee habitat in their fields, farmers could "hedge their bets in the event of honey bee scarcity through partial replacement of honey bee by native bee services." In the decade since, other researchers have cited the paper—now seen as prescient—614 times. During that period, CCD has joined the already long list of maladies afflicting honeybee hives, and the economic fortunes of beekeepers have grown increasingly perilous. "Bees," says Kremen, who won a "genius" grant from the MacArthur Foundation in 2007, "are telling us something very fundamental about our agricultural system and how off-balance it is."

Kremen's work is now funded in part by the U.S. Army, which wants to safeguard the nation's food security. "It's a component of creating a resilient system," she says. Plants that require animal pollination contribute 98 percent of the total vitamin C supplied by major global crops, 70 percent of vitamin A, 55 percent of folic acid and 74 percent of lipids. "If all the pollinators went extinct, we probably wouldn't starve," Kremen says. "But we'd all have scurvy or some other vitamin-deficiency disorder."

The honeybee crisis underscores the tremendous risk we have unwittingly built into our farm system by relying on a single insect to pollinate so much of our food supply. As author Hannah Nordhaus put it in her book *The Beekeeper's Lament,* "Farmers expect bees to function like yet another farm machine—like shakers, sweepers, tillers and combines." But honeybees are living creatures, subject to the realities of biology. And despite 400 years of domestication, there are still many things about honeybee biology we cannot control—for instance, the insects' susceptibility to parasites, viruses and climatic conditions. They may be domesticated, but they do not exactly stay in a pen as cattle do.

There are other things we *can* control: namely, the environmental factors that govern the bees' life cycle. As it turns out, we have engineered an environment that, in some ways, could not be worse for the bees. "Our monoculture system," Kremen says, "is creating a huge demand for an army of pollinators, and there's virtually no way to ensure that except for bringing in honeybees. If they're sick and having problems, what are we going to do?"

GHOST SHIPS

WHAT WE KNOW as the honeybee is more accurately called the European honeybee (*Apis mellifera*), which first arrived with early colonists on ships from England sometime around 1620. From the beginning, various pests and pathogens plagued hives, and beekeeping was a battle to stay a step or two ahead of the grim reaper's scythe. Wax moths, American foulbrood, drought, nosema disease: these are just a few of the things that have doomed both hives and beekeepers through the centuries.

In the fall of 2006 a now legendary beekeeper named Dave Hackenberg discovered that 360 out of his 400 hives in Florida were lifeless—no bees in sight. "They waited, fully stocked with pollen, honey, and larvae—like ghost ships—for their inhabitants to return," Nordhaus wrote. "But the bees never came back."

By the following winter some beekeepers had lost 90 percent of their hives; across the country a third of honeybee hives collapsed, many in this same mysterious way. Researchers named such disappearances "colony collapse disorder," although the term quickly became a metonym for all the maladies afflicting honeybees.

Scientists have failed to find a single culprit that is primarily responsible for CCD. A flurry of recent studies implicates neonicotinoids, or neonics, a widely used class of pesticides, but they probably do not deserve all the blame. The most likely scenario is that neonics are an indirect cause of bee declines, leaving colonies far more susceptible to pathogens such as the parasitic fungus that causes nosema disease and varroa mites—rust-colored parasites that suck out bees' vital fluids and spread crippling viral diseases. (In Australia, where neonics are heavily used but there are no varroa mites, honeybee colonies remain healthy.) Other contributing factors include fungicides, drought and an inadequately diverse diet.

The meta problem may be that our agricultural system is simultaneously dependent on honeybees and contributing to their demise. Relying on a single bee species to pollinate nearly 100 different crops is untenable. Every year beekeepers truck their hives around the country in the back of tractor-trailers, following the flowering of various crops: almonds to cherries to apples, and so on. Often, when no crops are in bloom, the bees do not have a lot to eat. Beekeepers supplement their diet with corn syrup or sugar water, which do not have nearly the nutritional value that natural pollen and nectar do. On top of that, during huge crop pollination events such as the almond bloom, around 1.5 million hives from around the country converge in California, creating near-perfect conditions for transmitting diseases. Imagine a giant gathering of kindergartners from every region of the nation, all intermingling their germs.

FLOWER POWER

ON A SUNNY DAY in early April, not long after the almond bloom has faded, I set out to see what Williams, now at U.C. Davis, and Kremen are up to. Next to a field of walnut trees near the university, a row of tall shrubs planted by the researchers stretches for several hundred yards: western redbud, coffeeberry, gum plant, sage, coyote brush. The bushes are in varying stages of bloom, and tiny, black bees fly from flower to flower. They are mason bees, known for building mud apartments inside wood dwellings.

Last year Kremen and her team recorded a total of 130 species of native bees lured to hedges neighboring 40 different farm fields. Based on historical records, California was once home to as many as 1,600 native bee species, although it is unclear how many of these persist today. A recent study published in the journal *Science* found that in a span of 120 years, Illinois lost half its wild bee species, largely because of diminished numbers of wild flowering plants. Another study concluded that four species of American bumblebees have lost up to 87 percent of their habitat, slashing their ranks by 96 percent.

Kremen is hoping to prove not just that her hedgerows attract bees, which is already clear, but also that they are increasing the overall number and diversity of bees in the area rather than siphoning bees from elsewhere. "It's possible that you plant this hedgerow and it sucks all the native bees from the landscape," says Leithen M'Gonigle, a postdoctoral researcher in Kremen's lab. "When your crop is flowering, you don't want the hedgerows to be more attractive." In other words, the architecture of restoration might matter a lot.

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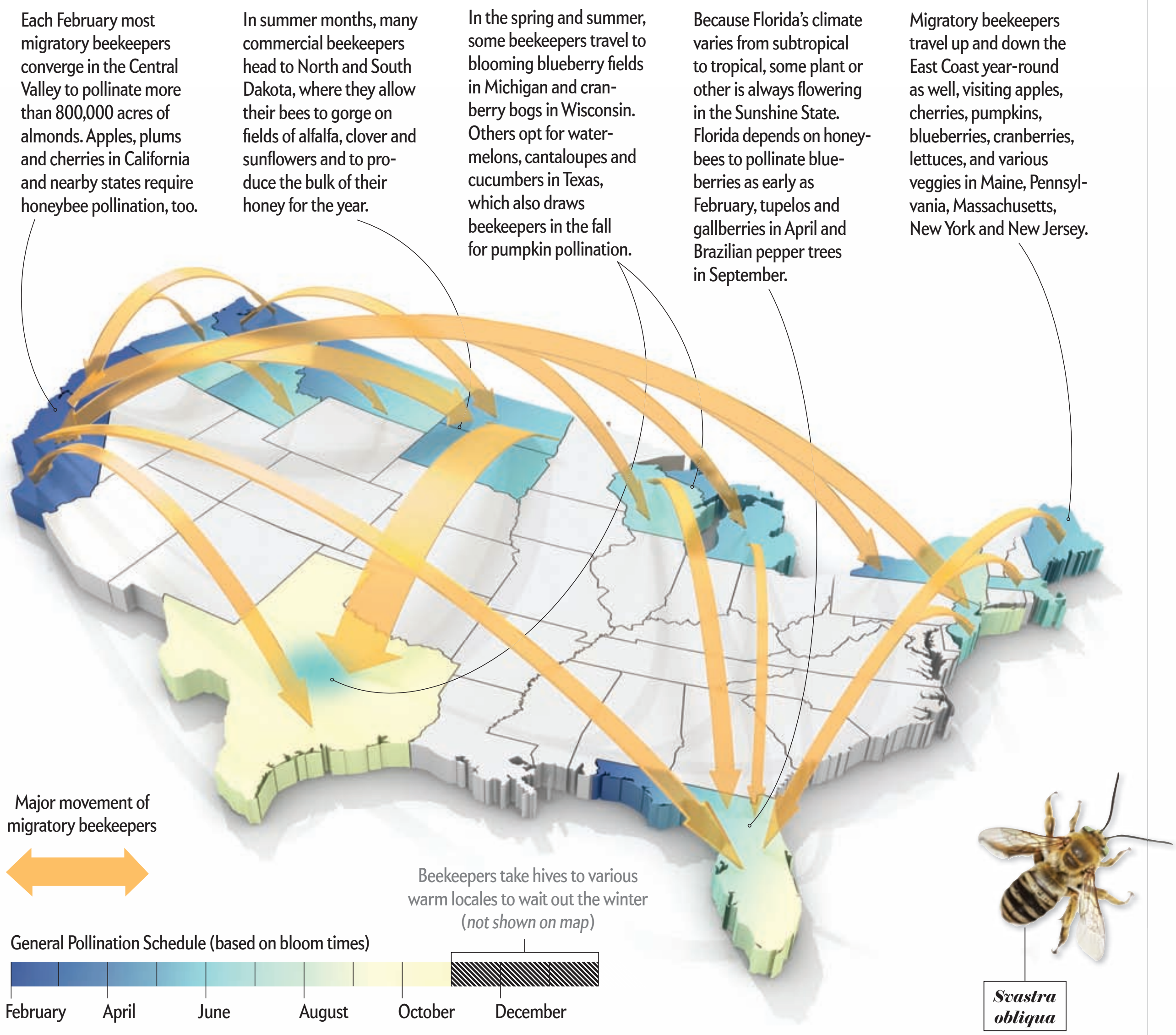
At a research farm owned by U.C. Davis, a giant bed of knee-high plants, some already budding and flowering, has taken root between neatly organized crop rows that run to the horizon. Here Williams is experimenting with forbs—perennial and annual flowering plants—that could appeal to farmers who do not want to deal with the hassle of woody plants on their fields. The nine plant species in Williams's current experimental mix are drought-tolerant, native, and selected to maintain diversity and abundance throughout the season.

Scientists also hope to learn more about how native bees and honeybees interact. In a study published this year researchers from Williams's and Kremen's labs found that honeybees became even more effective pollinators of almond trees in the presence of both various native species and blue orchard bees, a managed species. The more efficiently honeybees work, the fewer are needed to pollinate a given field. The investigators are now studying whether a specific chemical footprint left by the native bees in fact alerts the honeybees to extra competition.

Hedgerows and wildflowers sound like the province of mild-

Bees without Borders

In the U.S., many farmers cannot rely on native bees or even local honeybees to sufficiently pollinate their vast swaths of cropland. Rather they rent honeybee hives from the 1,600 or so migratory beekeepers who traverse the country between February and November. This annual migration mingles sick insects with healthy ones and deprives bees of proper nourishment when on the road.



Svastra obliqua

mannered gardeners puttering about in floppy hats. Yet as mundane as the whole thing may seem, restoring native habitat to farmland could represent the start of an agricultural revolution—one that could make much of our food supply more sustainable. No existing technology can pollinate crops. In southwestern China, where a combination of habitat loss, wanton use of pesticides and overharvesting of honey has wiped out bees, workers pollinate apple and pear orchards by hand, transferring pollen from one flower to another with small brushes. Such a massive effort is far too labor-intensive for the U.S., where it would render fruit prohibitively expensive. Bees—not just honeybees but all bees—are our only hope.

One way scientists aim to jump-start this agricultural revolution is with a program called Integrated Crop Pollination, or ICP. Funded by the U.S. Department of Agriculture, ICP consists of a series of options and steps for supplementing honeybees—including expanding habitat, reducing pesticide use and adding in other managed pollinators. Currently several other bee species, such as the blue orchard variety, are commercially available and may help farmers supplement honeybee populations.

Illustration by Bryan Christie

ICP began as an idea flitting about the mind of Rufus Isaacs. As the resident blueberry entomologist at Michigan State University, he spends a lot of time among the fruiting shrubs. While researching ways to control Japanese beetles and other blueberry enemies, he began to notice all the bees. Honeybees, yes, but also Michigan natives such as plump *B. impatiens* bumblebees, hairy-shouldered *Andrena bees* and small, black *Ceratina* bees that nest in thin, hollow stems. Isaacs realized that no one really knew which bees, or how many kinds, were out there. So Julianna Tuell, then a graduate student in his lab, set about categorizing them. She found 112 species of native bees zipping through blueberry fields in bloom and an additional 54 species active before and after the flowering.

Most of the native bees were solitary varieties: individuals that make their own nests in the soil rather than living in social hives. The most common species was *Andrena carolina,* a medium-size brown bee that gathers pollen only from plants in the blueberry family, including cranberry, huckleberry and azalea. Overall, though, the bulk of the bee species were generalists, collecting pollen from a wide range of plants.

A few years ago Isaacs, like Kremen, decided to find out how much wild bees contribute to blueberry pollination. Researchers have estimated the value of wild bee crop pollination in the U.S. at $3.1 billion a year; honeybee pollination is worth roughly $15 billion. Isaacs discovered that in small fields of less than an acre, wild bees took care of 82 percent of pollination. In big fields—1.5 to 16 acres—wild bees accomplished only 11 percent of pollination. Because the bulk of Michigan's blueberries are grown on large farms, Isaacs estimated that wild bees provide just 12 percent of the state's blueberry pollination. That is nowhere near enough to serve as insurance against honeybee declines, he says.

Yet if farmers had an economic incentive to add habitat—on fallow fields or in areas that are frost-prone, have poor soil or are otherwise unfit for blueberries—the story could be different. A graduate student in Isaacs's lab investigated pollination in five blueberry fields of up to 10 acres, with up to two acres planted with native Michigan wildflowers in a mix that blooms from spring until early fall. The study, not yet published or peer-reviewed, showed that booming native bee populations increased blueberry yields to such an extent that farmers could recoup the cost of establishing habitat in three to four years. Setting up habitat costs around $600 per acre, Isaacs says, but the USDA's Natural Resource Conservation Service has programs that will cover between 50 and 90 percent of the expense.

Researchers continue to seek out the best ways to nurture native bees, but farmers can start improving crop pollination now. Gordon Frankie, a U.C. Berkeley bee biologist whose office sits directly above Kremen's, has spent more than a decade designing bee habitats for urban gardens, and now he has begun applying that knowledge to agriculture. "You can't have a one-size-fits-all approach," Frankie says. "Each farm will be different, with different needs. But the idea is that we'll be able to write a prescription for any farm—you need this, this and this." On four farms in Brentwood, Calif., about an hour outside Berkeley, he has planted a mix of shrubs and forbs near blackberry bushes and cherry trees. Frankie hopes to create a series of case studies—"an orchard cropper, a row cropper, 25 acres, 145 acres"—that he can use to reach out to similar types of farms.

Meanwhile, using data from Kremen, Williams and others, the Xerces Society has partnered with the USDA's Natural Resource Conservation Service to build a "pollinator-enhancement program." Since 2009 the group has trained more than 20,000 people—farmers, USDA representatives, cooperative extension agents—in the value of native bees. It has also developed a set of concrete guidelines for farmers, explaining how to plan a meadow to attract native bees and to minimize the effect of pesticides.

A farm set up to welcome native bees could, ultimately, be better off than one reliant on honeybees. More than 20,000 species of native bees are abuzz around the world; collectively, they are exceedingly more likely to recover from disease or extreme weather than any one species of pollinator. Kremen believes the hedgerows are only a first step. The real challenge will be scaling up to 1,000-acre farms, bringing pollinators back to massive monoculture operations. She envisions a system where farms are divided into blocks that bloom at different times, so there is always food for pollinators to eat.

It is a system some farmers are already embracing. In the Central Valley, Frank Muller and his two brothers farm a diverse assortment of conventional and organic crops for chain stores such as Safeway and Walmart, including canning tomatoes, pickling cucumbers, and everything from almonds to wine grapes to sunflowers. The Mullers have planted habitat to attract native bees and have started their own on-farm honeybee operation. "They can be in our crops all the way from February through August or September," he says. The farmers will also put in plants specifically chosen to provide nectar in the remaining months. "We're not going to lose our bees," Muller says of the crisis. "We just need to manage them differently."

For now the Mullers are still in a minority. Not all farmers are ready to upend their long-standing ways of doing things—or pay—to bring in more pollinators, at least not until the honeybee predicament directly harms them. As honeybees continue to suffer, though, more and more farmers may change their minds.

M'Gonigle thinks the honeybee crisis could be "a kind of blessing in disguise" because "it forces us to think, 'What are we going to do to keep our food production going?' In the long term, it might be that we look back and say, 'Wow, this was a good thing, a good way of getting us to reprioritize and start thinking about conservation of native species.'"

As I watch a mix of honeybees and their wild cousins dart among purple flowers in one of Kremen's hedgerows, it is easy to see what he means. Our entire modern-day agricultural system has grown up with honeybees, so we have never had to really consider the fact that relying on a single pollinator is probably not sustainable. This may be a window of opportunity—even if climbing through it could sting a little.

MORE TO EXPLORE

The Beekeeper's Lament: How One Man and Half a Billion Honey Bees Help Feed America. Hannah Nordhaus. HarperCollins, 2011.

Are Neonicotinoids Killing Bees? A Review of Research into the Effects of Neonicotinoid Insecticides on Bees, with Recommendations for Action. Jennifer Hopwood et al. Xerces Society for Invertebrate Conservation, 2012. **www.xerces.org/neonicotinoids-and-bees**

SCIENTIFIC AMERICAN ONLINE
To learn more about almond pollination in California and migratory beekeeping, visit **ScientificAmerican.com/sep2013/migratory-beekeeping**