United States Department of Agriculture

Natural Resources Conservation Service

6200 Jefferson NE Albuquerque, NM 87109

April 17, 1997

BIOLOGICAL TECHNICAL NOTE NO. NM-45

SUBJECT: ECS - ESTABLISH MODELS FOR POLLINATOR CONSERVATION AND ENHANCEMENT BENEFICIAL TO FARMING.

Purpose. To distribute information to the field.

Effective Date. Effective when received.

Filing Instructions. File in the Biology Technical Note binder.

We recently received information from The Arizona-Sonora Desert Museum's "Forgotten Pollinators Campaign", in Tucson, AZ.

Can you name ten pollinators in your field office area?

According to the Campaign, ten essential reasons to protect pollinators include:

1. The future of our farms depends on pollinators.
2. We need to appreciate the benefits that a diversity of pollinators provides.
3. Honey bees are in decline.
4. All pollinators require protection from toxins.
5. Habitat loss is a major threat to pollinators.
6. Fewer pollinators ultimately mean fewer plants.
7. Endangered species protection need not be incompatible with food production.
8. Plants and pollinators both need protected habitat.
9. Migratory pollinators require interstand AND international protection.
10. Pollination is a threatened ecological service.

When you thought of the ten pollinators, did you consider insects, birds, and mammals? What about other pollinators?

Soon, NRCS will be making seeding recommendations for CRP contracts, as well as other cost-share programs. We strongly suggest that plants that will benefit pollinators in your area, such as legumes, wildflowers, and shrubs be included in the vegetative mixes. During wildlife planning, do not forget wildlife such as birds and bats.

Attached is a copy of "Partners in Production," a brochure provided by the Forgotten Pollinators Campaign, and reproduced with their permission. We ask that you share this information with the Local Work Group and SWCD, and with clients as needed. You might want to use the questionnaire in the back when planning with clients, to gather information about their pollinator needs.

If you have questions, or need additional information, you can contact Wildlife Biologist Gary Wooten at 505-761-4486.

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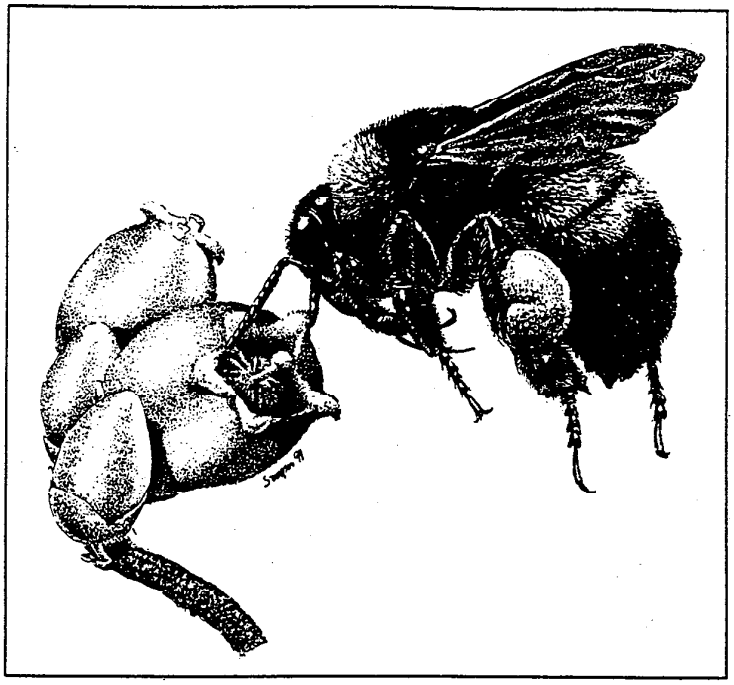
Partners in Production:

How to work with pollinators to improve your harvest



A native southeastern blueberry bee buzzes a highbush blueberry flower. Drawing by Blair Sampson

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If you've seen abundant honey bees on your farm lately, count yourself among the lucky. Beleaguered by mites, disease, pesticides, bad weather, and the invasion of Africanized honey bees, the crop-loving European honey bee has been the subject of dire predictions of doom and loud proclamations in its defense. USDA numbers indicate that we've lost over half the wild and domestic colonies that we had on farms and ranches in 1950, and half of that loss has occurred since 1990. Whether or not the honey bee is indeed on a collision course with destiny, the discussion has brought an often overlooked aspect of food production into focus - pollination.

"A modern farmer can't assume that pollination of his fruit and vegetables will just happen," say South Carolina beekeepers, Dave and Janice Green. "The pollination scene is a rapidly changing story, and pollination has to be managed, just like fertility, or pest and disease control."

Pollination is crucial for the production of viable seeds and for fully developed, tasty fruit. From the experience of many of us who grew up on farms, this critical process just happens naturally, without any high-tech intervention. For grains and some nut crops, the wind ensures seed set; but for most fruits and vegetables, insects come into play. Largescale fruit and nut growers like California's almond producers, who think a lot about pollination, usually depend on beekeepers to provide adequate numbers of domestic honey bees when the crops are in bloom. However, honey bee populations have recently declined, and commercial pollination fees have increased in parts of the country. If you grow on a smaller scale, you may find renting or keeping bees expensive. Some growers report only recently noticing spottiness in their orchards and misshapen fruit, indicating pollination problems.

"All of our local wild bees are gone," reports H.K. Johnson a beekeeper in Harnett County, North Carolina. "Our watermelons produce only three to five fruits in a whole field - the future looks grim."

The decline of honey bees, however, does not mean crop failure. "We have not had problems with pollination on our small farm because we raise several kinds of bees and encourage pollen and nectar-producing plants throughout the year," says Raymond Williams of Beetberry Farm, New York. "There is, however, a critical shortage of pollination in the Northeast, as almost all, if not all, of the feral honey bee colonies have now been destroyed by mites. Many produce farmers in the Northeast are noticing decreases in production."

Whether you rent hives now or have never given two cents for a pollinator, determining what kinds of bees pollinate your crops and what you can do to work with them, will go a long way towards improving the size, quality, and dependability of your harvests. Even if you aren't experiencing yield declines, better pollination can provide you with better looking and tastier harvests. The time is ripe.

Alternative pollinators

There are several kinds of bees - both managed and wild -- that effectively pollinate crops. Honey bees are generalists, and will visit many different kinds of crops. But they are also relatively short-tongued, so are of little value for deep flowers such as red clover. Honey bees also cannot "buzz pollinate", which involves vibrating the flower parts so that pollen is released. Crops that are greatly enhanced by being buzz pollinated include: southern "rabbiteye blueberries, cranberries, tomatoes, chili peppers, eggplants, and kiwis -- 10% of the world's flowering plants. Among the effective buzz pollinators are the bumblebee and the blueberry bee, both native to the U.S. Another wild native pollinators include squash and gourd bees, which are frequently found nesting in squash and pumpkin fields around the country.

Leafcutter Bees and Mason Bees: These usually black bees include many native to the U.S. that use leaf pieces, resins and sometimes pebbles to construct their nests in abandoned beetle burrows in wood or underground. They are important pollinators which carry their pollen loads dry on a special brush underneath their abdomens. Farmers and homeowners need to tolerate the small levels of plant damage (circular snips taken out of leaves like roses) they cause and remember their essential role as pollinators. One type of introduced (to the U.S. in the 1930's) leafcutter bee is the Alfalfa leafcutter bee. We have learned to manage its nesting on a commercial scale and it will nest gregariously by the thousands in special "bee boards" made of wood or styrofoam or in paper straws. Thus, they can be moved around with vehicles just like honey bee colonies. The best part is that they don't sting people and are super efficient pollinators of high value crops like alfalfa. Honey bees don't like to visit alfalfa blossoms since the floral parts are held together with great force. When honey bees land on them, they get hit in the head or even knocked off the flowers. The tough little female Alfalfa leafcutter bees don't seem to mind and actually seek out alfalfa and other legume flowers to visit in their daily searches for pollen and nectar.

Mason bees use mud in their nest construction. One especially valuable and easily managed mason bee is the "Blue Orchard Bee." It will actively seek out drilled boards or paper straws in which to nest. These bees are especially used for the pollination of backyard and commercial apple and other fruit orchards. Just 350 female orchard bees can pollinate an entire acre of apple trees that normally would require tens of thousands of honey bees from a rental colony.

Bumblebees: Along with honey bees, "digger bees", orchid bees from the American tropics, and tropical stingless bees, the familiar black, yellow, red and white bumblebees are social bees that are exceedingly efficiently pollinators. Bumblebees are most common in the northern temperate areas of the world. Canada, the northern U.S. and Europe all have many dozens of native species. Bumblebees form colonies with one queen, some males and several hundred sterile female workers. They have long tongues and are especially useful pollinators of deep blossoms such as red clover which honey bees cannot pollinate. Recently, "bombiculture" has developed with the knowledge of how to rear/raise colonies year around for commercial pollination uses, especially within glasshouses for tomato production. Honey bees are inefficient pollinators under glass since they are always trying to escape, unlike the busy bumblebees which settle down to forage on the blossoms. Additionally, honey bees are unable to use floral sonication ("buzz pollination") to pollinate such crops as blueberries, cranberries, eggplant, chile peppers, tomatoes and kiwi fruits. Bumblebees actively turn themselves into "living tuning forks" and merrily buzz the pollen out of these highly modified blossoms. Bumblebees will come to play a greater role in agriculture in the coming years.

What is pollinating your crops?

One reason many growers are not experiencing declines in yields, even as the wild honey bee is disappearing, is the presence of many other wild bees who are not vulnerable to the same diseases and pests. The Forgotten Pollinators Campaign sponsored field research this summer on pumpkin and squash fields in Maine, Alabama, and Arizona to find out how pollinating was being done. In all three states, the researchers found that in fields that may have once been primarily pollinated by feral (gone wild) honey bees, the lion's share of the pollination job is being done by native bumble bees, squash and gourd bees and their wild kin.

Are your crops under-pollinated?

"Symptoms of inadequate pollination (as opposed to nutrient deficiencies or disease) are often unrecognized," says Dave Green. "The poor quality is often blamed on weather or other factors. It surprises me how many growers don't know the simple and basic tool of counting seeds for apple pollination evaluation, for example" he says. "We may perpetuate false ideas by referring to apples as being "set," when we really should talk about seeds being set. It requires *multiple* visits by a bee to each blossom to make the apples that make the money."

To find out how well an apple was pollinated, simply slice the fruit crosswise and check for two seeds in each of the five seed pockets. Count only fully developed, not withered, seeds. The bagged supermarket apples usually have only two or three seeds, while large gourmet apples may have six or eight. Green suggests that growers keep yearly records on how well varieties are pollinated along with any information like how many honey bee colonies were rented, where they were placed, or what other native bees may have done some or all of the pollinating in your fields.

What you can do to create a pollinator-friendly environment:

Lack of suitable pollen and nectar plants present a fundamental problem to the wild bees you may rely on for pollination. All too efficient herbicides, and the removal of fence-rows, wild strips, and fallow lands all reduce forage and nesting sites for wild bees. Sweet clover is eliminated from fields by herbicides, for example, but is also replaced by herbicide-tolerant plants like Dalmatian toadflax, yarrow, and deadly nightshade, that offer almost nothing for bees.

If you have any arable land or wood lot acreage you can sow to green manures or cover crops, you can encourage native plants that offer food and shelter to wild bees. Clovers, alfalfa and other legumes, sunflowers, thistles honeysuckles, sweet milkweeds, sages, salvias, beebalm and other mints (bees love mints) are just a few of the many plants that provide wild bees with nectar and pollen.

- On his 18-acre fruit and vegetable farm in New York, Raymond Williams grows mixed nectar plants for bee pasture to support wild bees and the bees he raises, which include honey bees, orchard bees, hornfaced bees, blueberry bees, and alfalfa leafcutter bees. "We grow about six acres of nectar plants including red alsike, dutch white, and sweet clovers, birdsfoot trefoil and alfalfa. Also annually, we plant buckwheat for bloom at varying times. In the fall, golden rod and New England asters are everywhere."

- Goldenrod provides especially important food for bees, since it is one of the last heavy-yielding plants of the season and the pollen is high quality for bees. Unfortunately, goldenrod is often falsely blamed for allergies caused by ragweed and so is often kept mowed.
- Many of the practices that will encourage wild pollinators in your fields, will also encourage other beneficial insects. Richard de Wilde in western Wisconsin shelters beneficials in his vegetable fields with 8 foot wide hedgerows. He plants an understory of grass mixes like creeping fescue and ryegrass with a row of shrubs and a row of flowers. Grasses can supply pollinators with shelter and resting places. Depending on shrub selection the hedgerows cost 38 to 88 cents a foot. He looks for flowers and shrubs that bloom throughout the year in order to provide a continuous source of nectar and pollen. He also plants ones that have a good shelf life because he markets them with the vegetables. He plants black-eyed Susan, purple coneflower, daisies, dogwoods, and curly willow.

How to make your farm hospitable to Bumblebees

Bumblebees are excellent pollinators of many crops. They are robust workers, often willing to brave winds and temperatures that send honey bees into the hive. They make their annual colonies in grasslands and prefer undisturbed places, away from plowing and herbicide treatments that may destroy grass or old nests of birds and burrows of small mammals that the bumblebees also use. Bumblebees store very little honey so need to forage every day or two. They rely on a continuous succession of flowers from spring to autumn. Typically, they prefer large flowers with abundant nectar, like white and red clover, field bean, raspberry, carrot, oilseed rape, birdsfoot trefoil and borage. These are plant species that have flowers like the crop the bumblebee is pollinating. If you leave hedgerows and other set-asides for wild bees, avoid spraying and plowing for several years which will allow perennial plants to establish themselves. Mow occasionally to prevent scrub invasions, but avoid it in the summertime when plants bloom.

How to spray if you have to -- or how to talk to neighbors who spray

Not everyone farms organically. But as many beekeepers are well aware, the risks of pesticides extend far beyond the boundary of a field. Growers, homeowners, and even state-run insect and weed control programs may not be fully aware of the implications of their spraying practices. Here are a few guidelines for minimizing the negative effects of pesticides on pollinators.

- *Don't spray when pollinators are at work.* Whether you use honey bees or rely on wild bees it is essential that you monitor for foraging bees as pesticide labels require. "I am firmly convinced that pesticide misuse is a bigger problem than Varroa mites," says beekeeper Dave Green. "It certainly has cost me a lot more dead and weak hives." David Pimental of Cornell University has done research indicating that one in every five honey bee colonies that has died in recent years was made critically vulnerable by exposure to pesticides - an exposure that growers can avert at very little cost.

  Also, many states refuse to recognize that pesticide label directions do refer to wild bees as well as managed ones. Conformity with the label directions is required by law and is the responsibility of the pesticide applicator, but many applicators will assume that wild bees are simply not present, ignoring, for example, a weed bloom such as wild mustard in grain fields or clover in orchards, that will draw bees into the application area and lead to bee kills. Flowers outside the spray area, where drift may reach the flowers (clover blooming next to sweet corn, for example) also poses risks to pollinating insects.

In New York and Michigan, poison applications on blooming (tasseled) sweet corn can cause damage, because bees visit the tassels. The poisoning becomes much more severe when goldenrod is blooming in the fields or hedgerows, and aerial applicators contaminate this pollen, which is MUCH more attractive to bees than the corn.

Residual time (RT) of some common insecticides, (RT indicating the time needed to bring bee mortality down to 25% in cage test exposures. (Johansen & Mayer, 1990)

parathion	13 - 18 hours
malathion	6 hours
methomyl	2 hours
carbofuran	7 hours
chlordane	<2 hours
carbaryl, wp*	7 days
naled	12-20 hours
phosmet	>3 days
pyrethrum**	<2 hours

*liquid formulations of carbaryl are widely available and are much less residual than the wettable powder.

**Many of the modern synthetic pyrethroids (similar to pyrethrum above) have much shorter residual times.

- *Choose pesticides with pollinators in mind.* With the newer, non-residual pesticides that are often used today, bees are protected if the grower just doesn't apply during foraging time. Once the pesticide is dry, there is little further threat to bees. Residual pesticides such as Penncap M, Sevin, or any of the organophosphates should never be used during bloom. Not only is there a direct effect on bees visiting blooms, but residues are quite toxic and will be gathered in pollen and nectar and taken back to the hive to cause death in young bees and brood. Also, while the egg-laying honey bee queen stays in the hive and so is less exposed to the threats of a chemical kill, female leafcutting, orchard, and alkali bees all forage for pollen, and are thus exposed to pesticide residues. In 1980, U.S. economic losses due to pesticide poisonings of honey bees and reduced pollination was estimated at $135 million.
- *Even target-specific pest control agents can affect a wide range of insect life.* Bacillus thuringiensis, or Bt, a bacterial pesticide, has been touted as an environmentally rational approach.. But studies have shown that when Bt was sprayed to control gypsy moths in Oregon, numbers of non-target types of butterflies and caterpillars declined. Some of these insects serve as biological control agents themselves, or as important food resource for other wildlife.
- *Cooler weather means a dramatic increase in the residual killing action of insecticides.* Furadan has a residue hazard of one week in warm 70 degree weather, to greater than two weeks in 50 degree weather. Spur (fluvalinate), an insecticide considered non-hazardous to bees, gave a 30% increase in honey bee kills at cooler temperatures. Unusually cold nights following hot summer days causes lots of dew to form on leaves, which presents a bee poisoning problem as more of the chemical residue remains.
- *Climate affects the hazard of a given pesticide.* Malathion, for example, has a fumigant effect on bees in warm California, but not in cooler Washington. Phosdrin (mevinphos) has a short residue time in California, but will cause large bee kills a day later in Washington. In arid eastern Washington, Lannate (methomyl) is safe for bees if applied late in the evening, but in the east, less arid areas of the west, and in the Midwest, it is hazardous for a much longer period of time.
- *Use a lower-hazard formulation of pesticides when you must apply them.* Dust formulations are usually more hazardous to bees than sprays and granules. Wettable powders often have a longer residual effect than emulsifiable concentrates. Microencapsulated insecticides, which extend the life of the chemical through slow-release through the plastic walls of a capsule, are extremely hazardous to bees since the capsules are about the same size as pollen and adhere readily to bees.
- *Use lower-hazard application methods.* Systemic insecticides injected into the soil are safer than spraying them on plants. Fine sprays are safer than coarse ones. And ground application is much safer than aerial application, because the chemical drifts less, and smaller areas are treated at one time.

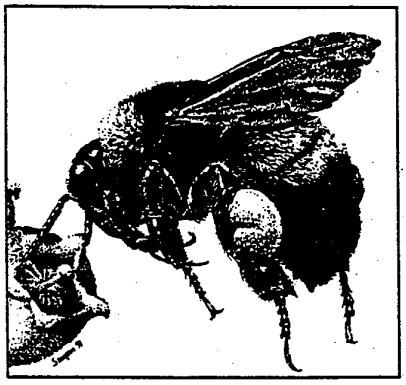
If You Rent Pollination Services:

Despite the struggles honey beekeepers have faced recently, they remain capable of moving large populations of pollinators into fields or orchards at bloom time - critical for largescale agriculture. California is probably the best example of a state where large-scale growers rely on rented colonies of honey bees to insure adequate pollination. California growers need to augment local bee populations for their crops of almonds,

plums, prunes, cherries, apples and other tree fruit crops, melons, and alfalfa. The annual value of these crops is several billion dollars, and to ensure adequate pollination California farmers rent about 1.4 million hives a year, about half for almonds alone. This accounts for half of all bee rentals in the entire country! California growers maintain such large and intensive operations that they must rely on contracts with migrating beekeepers from out-of-state.

Moving bees from state to state exposes them to mites, diseases, hybridization with Africanized bees, and risk of pesticide exposure – all of which are taking a heavy toll. According to USDA statistics, domestic honey bee colonies declined from 2.5 million in 1995 to 1.9 million in 1996 -- 20% in just one year. And this is following a decline of 25% between 1990 and 1995. California almond farmers have been feeling the results of these problems, too. In 1995, beekeepers were paid over $40 for each hive used for pollination rentals on almonds, a doubling of rental fees in ten years. Almonds require 30 to 60 percent fruit set for a successful crop, a task which requires two honey bee colonies per acre.

- *What to look for when renting a honey bee hive.* According to Dave Green, a grower should check the hives he is renting for pollination services. With the keeper's cooperation, a grower can often borrow an extra bee veil and do a simple check to see how many frames the bees cover in a hive. This will indicate how well the bees can provide pollination services. Ideally, says Green, the bees should cover seven to eight deep brood frames, which represents about five to six frames of brood. A hive with only five frames covered with bees is not quite up to par, unless most of the bees are out foraging. A hive with ten frames covered, on the other hand, may be too strong. Bees that have no space to develop will be apt to swarm. Swarmy bees have their minds on moving to a new home and are poor workers.



Help us provide growers like you with pertinent information on pollinators. Please take a moment to answer the questions below. Add as much information as you like, remove this last page from the booklet, and mail it in the stamped envelope to the Forgotten Pollinators Campaign at the Arizona-Sonora Desert Museum. Thanks!

Pollination Survey

Do you keep bees? If so what kinds (honey bees, Mason bees, Alfalfa leafcutter bees)?

Do you rent bees? How many and how often?

How large is your orchard/farm and what crops do you grow?

Have you experienced problems with pollination on your farm – such as areas of lower fruit set in your orchards, or misshapen fruits?

Have you noticed any changes in the abundance of bee pollinators on your farm in the last 2 - 3 years?

Are you certified organic? Do you, or your neighbors regularly use insecticides or microbial pest controls like Bt?

Do you, or have you, planted forages to attract/augment pollinators, or set land aside for pollinators?

What kind of information on pollination would be useful to you?

How do you get your information?

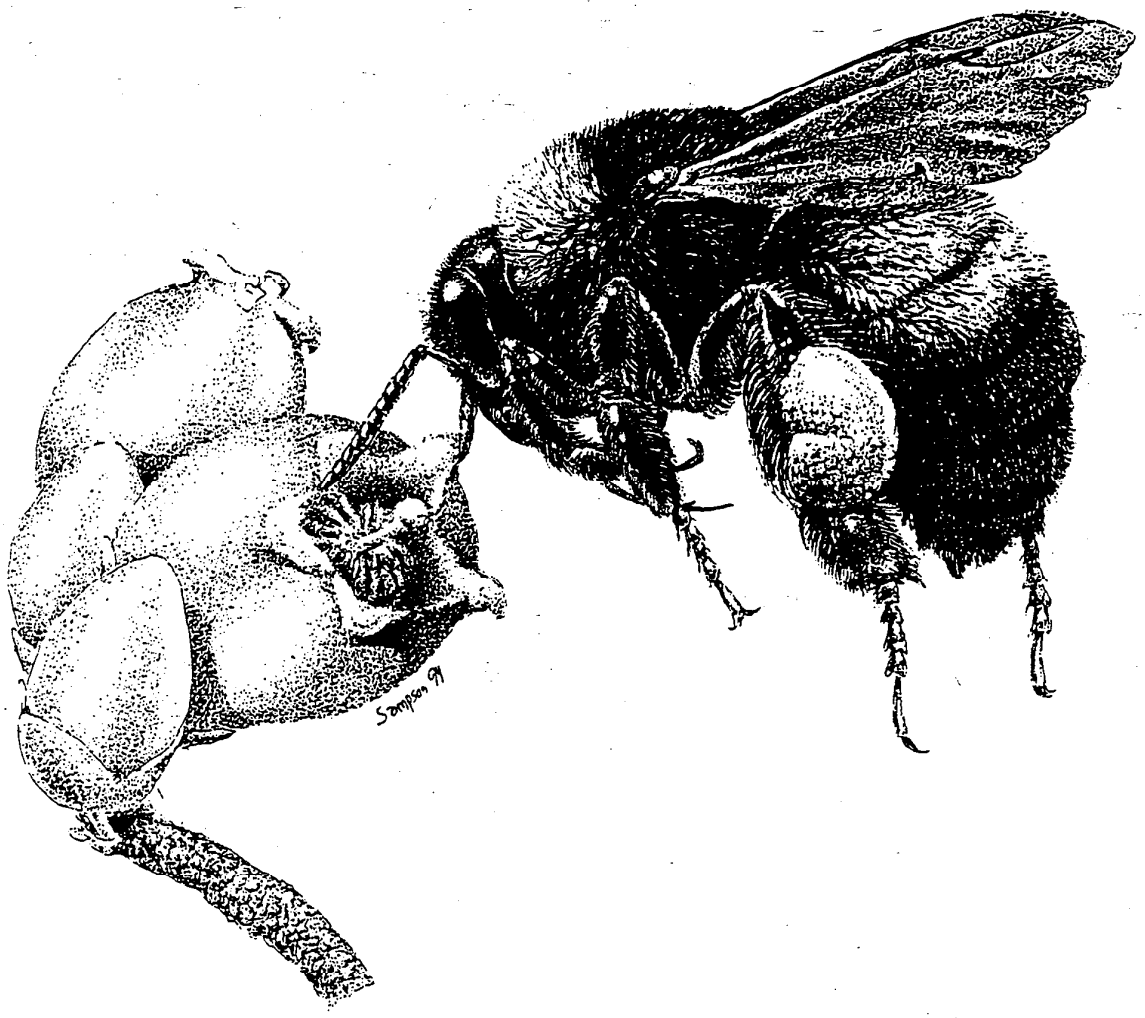
____extension agents/service

____magazines/journals (please list titles)

____the internet

___other (please describe)

TEN ESSENTIAL REASONS TO PROTECT THE BIRDS AND THE BEES



How an impending POLLINATION CRISIS threatens plants and the food on your table

SUMMARY

For one out of every three bites you take, you can thank a bee or other pollinator. Over three-quarters of the crop plants that feed the world, and many plant-derived medicines in our pharmacies, rely on pollination by insects or other animals to produce healthy fruits and seeds. Pollination--the transfer of pollen from one flower to another--is a fundamental ecological service provided by native bees, butterflies, bats, birds, and many other wildlife species. It can also be provided by managed honey-bee colonies, but they are declining rapidly--by 25% since 1990--and there remain fewer honey bees in the U.S. today than at any period in the last fifty years. At the same time, native bees and many other wild pollinators are increasingly threatened by habitat loss and excessive exposure to agrichemicals. Over one hundred and fifty species of bird and mammal pollinators (in one hundred sixty-four vertebrate genera) are of conservation concern, and untold species of invertebrate pollinators are threatened (see the Pollinator Redbook of Threatened Vertebrate Wildlife Species, compiled by Gary Nabhan, for the Forgotten Pollinators Campaign). Their conservation is made all the more difficult by the widespread assumption that pollination is a "free service" requiring no investment or protection, and by lack of public awareness that wild and managed pollinators are facing unprecedented threats.

These are not oversights we can live with. Pollinators play an essential role in the health of both wild and agricultural lands. If we do not take concerted actions to protect these pollinators, we stand to lose some of the very interactions between plants and animals that we depend on for diverse ecosystems and for a third of the food we eat. The Forgotten Pollinators Campaign joins food producers and consumers, scientists and educators, beekeepers and wildlife enthusiasts to urge appropriate actions in the public and private sectors to avert the impending pollination crisis.

Written by Mrill Ingram, Gary P. Nabhan, and Stephen L. Buchmann, with assistance from the Board of Advisers of the Forgotten Pollinators Campaign. 5/96

Edited and designed by Mrill Ingram
Cover by Blair Sampson; inside graphics by Paul Mirocha

Sponsored by:

Arizona-Sonora Desert Museum
Bat Conservation International
Center for Plant Conservation
National Wildflower Research Center
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For one out of every three bites you take, thank a bee, butterfly, bat, bird, or other pollinator. Pollination--the transfer of pollen from one flower to another--is critical to fruit and seed production, and is often provided by insects and other animals on the hunt for nectar, pollen, or other floral rewards. In fact, animals provide pollination services for over three-quarters of the staple crop plants that feed humankind and for 90% of all flowering plants in the world.

According to the U.S. Department of Agriculture (USDA), we are facing an "impending pollination crisis," in which both wild and managed pollinators are disappearing at alarming rates owing to habitat loss, poisoning, diseases, and pests (USDA-ARS 1991). For the first time ever, local bee shortages in 1994 forced many California almond growers to import the bulk of the honey bees they needed from other states to ensure that their $800-million-a-year crop would be pollinated. Recent monitoring of pumpkins in New York State determined that their blossoms were still laden with pollen five hours after they opened in the morning, long after they are typically stripped of all pollen by bees (Watanabe 1994). Endangered plants--like the Antioch Dunes evening primrose--fail to set fruit with more than a fifth of the seed they are capable of producing, because their most allegiant pollinators have disappeared. Concern that a decline in pollinators may destabilize food production and ecosystem functions globally has recently led to the formation of an international working group on pollination to advise the Sustainable Rural Environment and Energy Network of the United Nations' Food and Agriculture Organization.

Pollination is critical to successful ***commercial orchard and field-crop production, endangered species protection, urban gardening, ecological restoration, and forage production for the dairy and beef industries****. As food producers and consumers, scientists and educators, beekeepers and wildlife enthusiasts, we are concerned that a basic fact of life--our dependence on the functional relationships between plants and pollinators--is being ignored. We have joined together to urge appropriate action and public education on the following ten points.*

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1. The future of our farms depends on pollinators. Insect pollination is a necessary step in the production of most fruits and vegetables we eat and in the regeneration of many forage crops utilized by livestock. Growers of apples, almonds, cherries, blueberries, cucumbers, pumpkins, cranberries, alfalfa, and many other crops depend on insect pollinators--both managed and wild--to produce fertile seeds and full-bodied fruit.

Recent surveys document that more than thirty genera of animals--consisting of hundreds of species of floral visitors--are required to pollinate the 100 or so crops that feed the world (Prescott-Allen and Prescott-Allen 1990, Buchmann and Nabhan 1996). Only 15% of these crops are serviced by domestic honey bees, while at least 80% are pollinated by wild bees and other wildlife. (Yet, the USDA officially gathers economic data only on domestic honey bees.)

Action for farmers, agricultural policy makers, and researchers: We must recognize that pollination is not a free service, and that it requires investment and stewardship to protect and sustain. Economic assessments of agricultural productivity need to account for the "cost" of sustaining wild and managed pollinator populations. Policy makers responsible for the recent cut in long-standing subsidies to beekeepers for honey production have further jeopardized the pollination services provided by honey bees, estimated to be sixty to 100 times more valuable than the market price of honey (McGregor 1976, Southwick and Southwick 1992). Policy makers need to begin devising programs that reward farmers for implementing practices to protect the habitats of wild pollinators, and that provide incentives for those who wish to manage a wider variety of pollinators to assist farmers and orchard growers.

Action for researchers: The National Biological Service (NBS), the USDA, and private researchers should undertake complete inventories of the effective pollinators of cultivated crops and other valuable plants in the U.S. Scientists should also inventory the nectar resources and host plants that sustain the wild pollinators which visit crops. Entomologists need to research how populations of native insects can be managed for pollinating crops, and should regard them as genetic resources essential for sustaining agricultural yields in the future. Economists should make more comprehensive assessments of the economic value of pollinators, including wild species in addition to honey bees (Southwick and Southwick 1992). International agencies should encourage other countries to invest in similar inventories and assessments as well.

About 1 billion people--one-fifth of the world's human population--are undernourished because of chronic instabilities in food production and distribution. It is imperative that we conserve the wild pollinators that can, if properly managed, stabilize and even enhance crop yields (OToole 1993).

2. We need to appreciate the benefits that a diversity of pollinators provides.

A recent survey of zoo visitors in Washington, D.C. revealed that only a small percentage of the American public understands the process of pollination or the diversity of beneficial animals involved in providing services to plants (National Zoo 1994). For most Americans, pollen means allergies and bees mean stings.

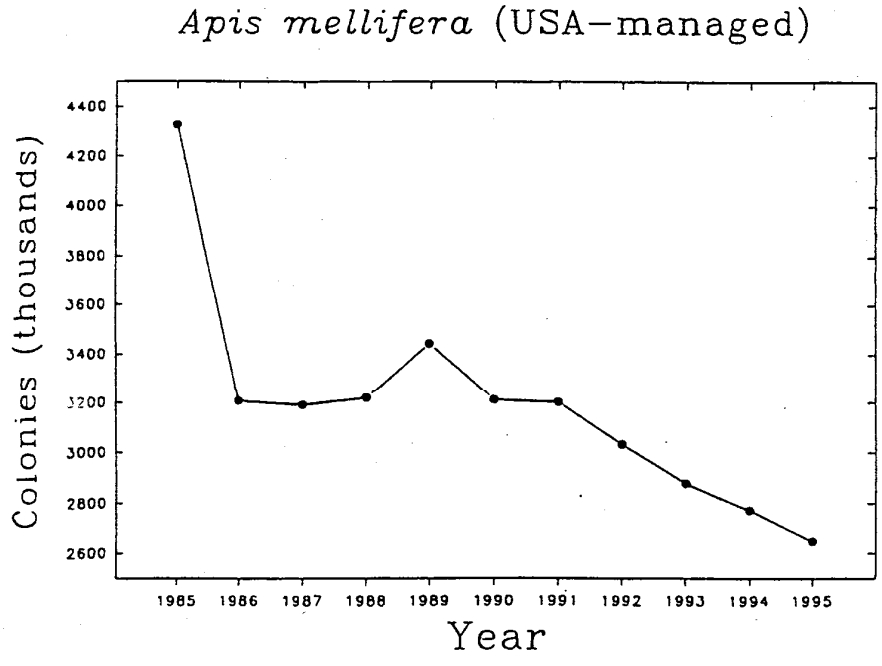
Pollination Basics: Pollination is the transfer of (male) pollen grains to the (female) stigmatic organs or ovaries in flowers. Some plants are wind-pollinated, others are self-pollinating, but most require insects or other animals to pollinate their flowers. A fertilized flower is more likely to produce full-bodied fruit containing a full complement of seeds capable of regeneration, while unfertilized flowers may "abort" or wither away without producing fruit. Even plants that are self-pollinated can have increased yields with insect cross-pollination. It has been estimated, for example, that cotton yields can increase by 10-20% when the plants are cross-pollinated. This remains an uncommon occurrence wherever cotton crops are treated with pesticides that impact insect pollinators (Pimentel et al. 1992).

Our recent analyses of global inventories of biodiversity indicate that more than 100,000 different animal species--and perhaps as many as 200,000--play roles in pollinating the 250,000 kinds of wild flowering plants on this planet. In addition to countless bees (the world contains an estimated 40,000 species of bees), wasps, moths, butterflies, flies, beetles, and other animals without backbones, perhaps 1,500 species of vertebrates such as birds and mammals serve as pollinators. Hummingbirds are the best-known wildlife pollinators in the Americas, but perching birds, flying foxes, fruit bats, possums, lemurs, and even a gecko function as effective pollinators elsewhere in the world.

Action for educators: We must encourage environmental awareness and appreciation for how humans need and benefit from biodiversity. Schools, museums, advertisements, and other public outreach and education efforts can direct attention to the interconnectedness among plants, humans, and other animals. Students are already using on-line networks like the program *Journey North* to learn about migratory animals including pollinators, and to track their movements.

3. Honey bees are in decline. The number of commercial U.S. bee colonies plummeted from 5.9 million in the late 1940s to 4.3 million in 1985 and 2.7 million in 1995. The loss of one quarter of all managed honey bee colonies since 1990 signals one of the most severe declines U.S. agriculture has ever experienced in such a short period. There are fewer bee hives in the U.S. today than at any time in the last fifty years. This demise has been brought on by the spread of diseases and parasitic mites, the invasion of Africanized honey bees, exposure to pesticides, climatic fluctuations, and the elimination of government subsidies for beekeepers (USDA-ARS 1991).

In recent years, some wildland habitats have lost 70% of their feral honey bees, which make hives in rocky outcroppings and other cavities (Loper 1995). Places around the U.S. are reporting pollinator scarcity (Burd 1994, Watanabe 1994). Such declines suggest that there may be far fewer honey bees servicing American



croplands and wildlands than at any time in the last half-century. The arrival of Africanized bees in ninety-nine U.S. counties since 1990 has forced some beekeepers to abandon their apiaries in highly populated areas, for fear of liable suits from neighbors. In addition, Africanized bees are among the carriers of parasitic mites infecting thousands of U.S. apiaries, killing off additional colonies (Hoff and Willett 1993).

Action for farmers and agricultural policy makers: Honey bee colonies need to be better monitored and managed to minimize further declines. Yet, the USDA is currently considering closing bee research laboratories. Bee research needs to be strengthened and also expanded to include research on the management of pollinators other than honey bees. It is estimated that native and introduced pollinators other than honey bees will provide $4-6 billion a year in services to sustain crop yields should the southern U.S. lose one-half or more of its honey bees (Southwick and Southwick 1992). Increasingly, they will have to deployed to take up the slack created by the decline of honey-bee colonies. Orchard growers and farmers need to ensure that neighboring wild habitats remain suitable for wild pollinators if they are to secure pollination services for their crops.

Alternative Pollinators: Alternative pollinators of agricultural crops already play important economic role in certain regions. The ground-nesting alkali bee, for example, is native to North America and much more expert at pollinating alfalfa for seed than are honey bees (O'Toole 1993). One acre of nesting habitat set aside for alkali bees can sustain sufficient female bees to pollinate 100 acres of alfalfa seed. There is growing evidence that native bees are also more efficient at pollinating orchard crops than are honey bees (O'Toole 1993). In the southeastern U.S., highbush blueberry farmers depend on wild southeastern blueberry bees for pollination. Each female blueberry bee can pollinate four to five gallons of rabbit-eye blueberries during her lifetime (Cane, 1988). Blueberries are valued at about $12 per gallon during midseason, so some farmers see these bees as flying $50 bills.

For such reasons, the USDA, SARH/Mexico, and Agricultural Canada should invest more of their resources in programs to manage a diversity of pollinators and to stabilize remaining apiaries. They need to implement programs that reward farmers for setting aside cropland and retaining hedgerows or windbreaks where wild pollinators nest and forage.

4. All pollinators require protection from toxins. Whether managed or wild, pollinators need protection from excessive exposure to the pesticides and other chemicals which can either poison them or impair their reproduction. These chemicals can also eliminate nectar sources for pollinators, destroy larval host plants for moths and butterflies, and deplete nesting materials for bees (Nabhan and Buchmann 1996a).

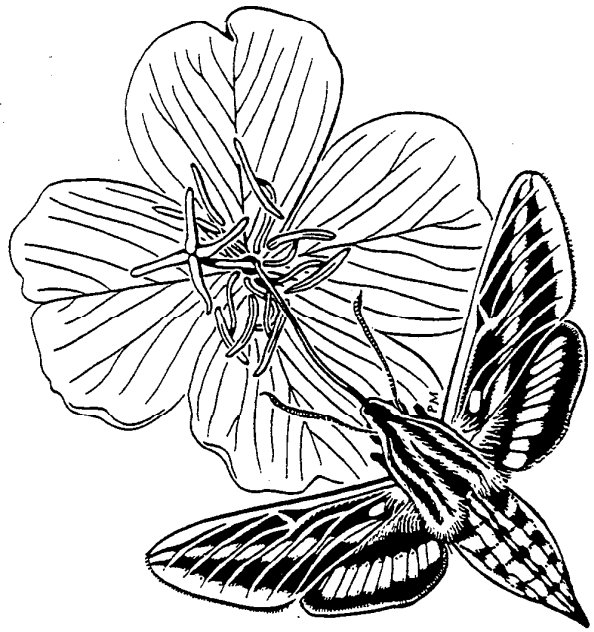
Few people realize that the U.S. now applies twice the amount of pesticides it used when Rachel Carson published *Silent Spring* in 1962 (Carson 1962, Curtis and Profeta 1993). In Canada during the mid-1970s, aerial spraying of coniferous forest pests reduced native bee

populations to the point that blueberry yields fell below the norm for four years (Kevan 1975). A large number of insecticides used in agriculture are toxic to pollinating insects, but only honey-bee colonies can be easily moved away from fields prior to spraying. Even so, it has been estimated that 20% of all losses of honey-bee colonies involve some degree of vulnerability to pesticide exposure. According to a study on the economic costs of pesticide use, honey bee poisonings result in an annual loss of $13.3 million (Pimentel et al. 1992). Wild insect pollinators such as small solitary bees are even more vulnerable than honey bees to the organophosphate pesticides that have largely replaced the organochlorides like DDT.

Moreover, many crops would benefit in quality and quantity from more thorough pollination but are not sufficiently pollinated because of heavy pesticide applications. Cotton harvests, for example, could increase by as much as 20% if the flowers were fully pollinated by bees. Farm income could potentially increase by $400 million per year. However, using bees to enhance cotton has proven impossible on a large scale where there has been continued intensive use of insecticides (Pimentel et al. 1992).

Field studies in the deserts of the U.S. have found that pollinators remaining in small fragments of natural habitat are particularly susceptible to insecticide spraying on adjacent croplands (Suzan, Nabhan, and Patten 1994).

Action for farmers, gardeners, and consumers: Pesticide applicators need training in monitoring pollinators as well as pests. Pollination ecologists familiar with particular species can work with pesticide applicators who know about timing and the drift distances of chemicals under various weather conditions (Holmbert 1993). When pesticides are applied by aircraft, as much as 50-75% of the chemicals sprayed can miss their target (Pimentel et al. 1992), leading to inadvertent exposure of nontarget organisms such as pollinators.



Integrated pest-management (IPM) techniques can provide alternative methods of weed and insect control that incorporate the use of habitat set-asides for beneficial insect populations and require the use of fewer toxins (National Research Council 1989). IPM strategies may help farmers reduce the costs involved in crop management, while allowing their produce to be

Action for environmental policy makers and researchers: We need on-ground surveys to determine safe setback distances from specific endangered species, rather than generalized guidelines which assume that the population dynamics and flying ranges of bats, bees, and beetles are all the same. Conservation efforts designed by the EPA, the USFWS, and other researchers need to recognize and include the web of interconnected relationships that sustain each endangered plant, rather than focusing on a specific species of plant or animal as if it were isolated. Likewise, agricultural scientists need to determine the ecological contexts required by beneficial insects that help sustain crop yields.

8. Plants and pollinators both need protected habitat. The last remaining natural populations of a rare evening primrose live in California's Antioch Dunes National Wildlife Refuge. Though the primrose is protected, its hawkmoth pollinator has not reappeared after years of pesticide spraying in nearby vineyards, and reproduction has remained low (Pavlik, Ferguson, and Nelson 1993). This plant remains in jeopardy as it produces few fruits and low percentages of viable seeds, while its weedy neighbors produce many. This is just one example among many where pesticide use, declines of certain nectar sources or larval host plants, and other threats have triggered the decline of pollinators of endangered plants.

Action for conservation biologists and environmental policy makers and wildlife watchers: Because of such "reciprocities," conservation policy and practice must move toward sustaining or restoring ecological *relationships*, rather than treating species as isolated organisms. *Critical Habitat* needs to be redefined to include the needs of both rare plants and their animal associates. When Critical Habitat has been designated for endangered plants, it has almost always been done without determining the foraging and nesting areas required to ensure sufficient pollinators and seed dispersers for long-term recovery of the plant in danger. The USFWS should require that pollination ecologists work to identify effective pollinators, determine their habitat requirements, and manage lands to sustain these animals as well as the plants.

Urban dwellers can also have a significant impact by providing nectar sources and nesting sites for pollinators. Even small backyards can harbor hummingbird feeders, gardens offering flowers that supply butterflies with nectar, and bee boxes. Pollinator gardening should become a high priority for garden clubs and native plant societies.

9. Migratory pollinators require interstate AND international protection. Bats, hummingbirds, moths and butterflies are among the pollinators that seasonally migrate long and short distances between mountain ranges, regions, and countries. Their migratory routes are often well-defined "nectar corridors" where the sequence of flowering over a season offers the pollinators sufficient energy to sustain their journey. Many of these nectar corridors are no longer fully intact, however; land conversion has eliminated some floral resources over twenty- to sixty-mile segments, in some cases longer than the distance energy-depleted pollinators can fly in one day (Nabhan and Fleming 1993).

Action for scientists, students, and international policy makers: Scientists and policy makers need to collaborate across political boundaries and regions to assess the continuity and health of migratory corridors used by pollinators. Because some migrants travel 2,000 to 4,000 miles a year, habitat loss in one area of their range may limit their populations overall. Certain migratory pollinator species aggregate in large numbers in temporary roosts that are vulnerable to human disturbance. Such roost sites should be protected throughout a species' entire range, since a refuge in just one portion will be insufficient to support viable populations. International policy agreements and environmental education efforts are needed to champion migratory pollinators.

10. Pollination is a threatened ecological service. The interactions between plants and their pollinators are essential to a viable structure and healthy functioning of wild and agricultural communities. Habitat loss, disease, and pesticides take their toll in different ways, but all of them imperil these vital ecological relationships, many of which developed through thousands of years of natural and cultural selection.

Three-quarters of the 100 or so crop species that feed the world depend on animals as the go-betweens to ensure that crops are pollinated. Sufficient food could not be produced without them. Roughly one-third of annual agricultural production in the U.S. derives from insect-pollinated plants. Crises like those now faced by the honey-bee industry demonstrate that we generally lack sufficient safety nets to protect agricultural yields. We can no longer justify devoting all research and management dollars to a single or even a few pollinators, and instead must support a diversification of the entire pollination industry.

In an era when human activities place increasing pressure on both natural and rural landscapes, we cannot ignore the vital role of pollination services and the frequently negative impacts that we are having on plant/pollinator relationships.

Action everyone can take: As a society, we need to recognize our debt to the "forgotten pollinators." To successfully confront the impending pollinator crisis, we must combine the strengths of everyone concerned. Foresters, entomologists, and conservationists need to devise workable plans for endangered plant species that include pollinators. Farmers, orchard growers, and other land managers need to consider pollinators as they make decisions about pesticides and land use. Educators need to emphasize the importance of pollinators in wild and agricultural lands and the interconnectedness of life in general.

Urban dwellers can include nectar and host plants for pollinators in their gardens, purchase organic produce, and rely on organic methods of pest and weed control in their own gardens.

Pollinator gardening provides hummingbirds, butterflies, and other wildlife with important sources of nectar, as well as increase our awareness of the diversity of ecological relationships in our own backyards.

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