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BioScience

November 1, 1999

SECTION: No. 11, Vol. 49; Pg. 857 ; ISSN: 0006-3568

IAC-ACC-NO: 57476085

LENGTH: 4530 words

HEADLINE: Pollination Migrates to Top of Conservation Agenda; efforts of biologists bring to public attention the vital role played by migratory pollinators

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BODY:

A collaborative effort on migratory pollinators aims to increase research, education, and conservation efforts

Three years ago, two biologists made an impassioned plea for the urgency of preserving the animal species that pollinate plants, and thereby put pollination squarely on the conservation biology agenda. In their book, *The Forgotten Pollinators*, Stephen L. Buchmann, research entomologist at the US Department of Agriculture's Carl Hayden Bee Research Center, in Tucson, Arizona, and Gary Paul Nabhan, director of science at Tucson's Arizona - Sonora Desert Museum, argued that preserving and restoring plant - pollinator interactions is crucial, not only to saving natural ecosystems but also to assuring the future viability of human agriculture. Two-thirds of wild plants depend on animal pollinators, as do three-quarters of crop plants. Habitat fragmentation, overuse of pesticides, and other threats, Buchmann and Nabhan contended, are threatening to extinguish these vital plant - animal interactions.

Their campaign has since gained many followers, including Interior Secretary Bruce Babbitt and media mogulcum-environmental philanthropist Ted Turner. Now, government support, private dollars, and a swelling cadre of biologists are pushing along Buchmann and Nabhan's vision of pollination conservation. In May 1999, at a conference in Tucson, Arizona, entitled "Migratory Pollinators and Their Corridors: Conservation Across Borders," over 100 biologists, resource managers, educators, and policymakers gathered to review research on pollinating animals that migrate between the United States and Mexico and to plan conservation priorities for these animals.

The conference kicked off a 5-year project of research, community stewardship, education, and conservation that aims to accomplish things to which conservation biology regularly gives lip service but often fails to achieve - meaningful collaboration across national boundaries and between basic and applied research, science and policy, researchers and educators, and scientists and the public. By focusing intensively on a few case studies in southwestern North America, the project's organizers hope to produce research results that are broadly relevant to other biological systems. They will also aim for accomplishments in preservation, restoration, education, and policymaking that can serve as models for other conservation efforts.

The migratory pollinators project focuses on four pollinator species: monarch butterflies (*Danaus plexippus*), lesser long-nosed bats (*Leptonycteris curasoae*), rufous hummingbirds (*Selasphorus rufus*), and white-winged doves (*Zenaida asiatica*). These species were chosen for their apparent importance in ecological processes of the arid Southwest, for their potential to allow links between research and education efforts, and because they each face factors that threaten their populations, according to Nabhan, who organized the conference and is spearheading the project. The bats and doves pollinate several plants, including columnar cacti such as **saguaros** (*Carnegiea gigantea*), and the hummingbirds and butterflies pollinate many other flowering plants. All four animals migrate between the United States and Mexico, the birds and bats traveling mostly in corridors between the Pacific Ocean and Mexico's Sierra Madre Occidental.

Although these four taxa were selected largely on the basis of research criteria, they (and some of the plants they pollinate) have undeniable popular appeal. **Saguaros** are the icon of the Sonoran Desert, hummingbirds and butterflies are beloved by legions of enthusiasts, and bats have fascinated people for centuries. The project's research on the four pollinators is intended to quantify migration's energetic costs, determine the flexibility of feeding and roosting requirements, document stress responses of animals encountering adversity along migratory corridors, and identify "flowering waves" - south to north progressions of plant flowering - and determine how tightly the movements of migratory animals track such waves.

Why migratory pollinators? Because, researchers say, migratory animals encounter more threats than resident animals and are especially vulnerable during migration. Long-distance migration has high energetic costs, leaving migrants little wiggle room when resources are scarce or conditions stressful. In addition, some migrants show fidelity to particular stopover locations, whereas others aggregate in communal roosts or feeding groups; such animals may depend strongly on the

preservation of key sites.

Migrating through drought-prone regions of northern Mexico and the Southwest United States can be tough enough, but the transnational migrants also face challenges posed by human activity. Conversion of natural vegetation to farmland and ranchland has been extensive in this region, fragmenting habitat along migratory corridors. Herbicide and insecticide use has skyrocketed in northern Mexico in the post-NAFTA (North American Free Trade Agreement) era, hitting insect pollinators particularly hard. Add to these threats others, such as invasive species and direct human persecution, and the migratory journey begins to resemble a refugee flight through a war zone.

Knowing where migrating pollinators travel is the first step toward conserving them, so a fundamental task is to determine exactly where migratory corridors are. As a starting point, Alberto Burquez Montijo, of Universidad Nacional Autonoma de Mexico, suggests focusing on the Sierra Madre Occidental, whose north-south axis creates a longitudinal alignment of habitats such as pine-oak forest and tropical deciduous forest. Burquez views the Sierra Madre as "a kind of conveyor belt" for north-south movement. But accurately identifying migration routes has proven to be an elusive goal. Fortunately, an arsenal of new technologies - stable isotope analysis, satellite radiotelemetry, and an array of molecular techniques - is emerging to supplement information gained from traditional banding and tagging methods. These "new tools for old questions," says Nabhan, promise that knowledge of migration patterns will build more quickly.

The four pollinators

Of the four pollinators that are the focus of the migratory pollinators project, the 3.5-inch rufous hummingbird flies the farthest. Its 6000-kilometer migration is the longest of any bird in terms of distance per gram body weight. Between Mexico and the Pacific Northwest, it refuels with nectar from flowers such as the bright red chuparosa (*Justicia californica*) and ocotillo (*Fouquieria splendens*).

William Calder, of the University of Arizona, wants to know what drives these birds' topsy-turvy population dynamics, how weather affects their migration, and whether migration routes vary from year to year. After measuring fat content on countless hummingbirds in transit and watching birds struggle through drought-stricken landscapes devoid of flowers, Calder, who has been studying the rufous hummingbird's physiology and migration patterns for many years, is convinced that the stresses of migration exert strong influences on this species' biology.

Currently, rufous hummingbird populations are in decline, and it's not known why. Burquez, a plant ecologist, has analyzed range maps of migratory hummingbird species in Sonora and found that hummingbird distribution is negatively correlated with areas of heavy agriculture and pesticide use. He speculates that agriculture may have wiped out a portion of these birds' historic migration path and that the same may be true for bees and other pollinators.

Calder's University of Arizona colleagues, avian physiologists Carlos Martinez del Rio and Blair Wolf, recently began studying the relationship between **saguaro** cacti and the white-winged doves that pollinate them. The huge and stately **saguaro**s - central to regional people's cultural identity and sense of place - may also be vital to the functioning of the region's ecosystems, they believe. **Saguaro**s provide nectar, pollen, fruit, and water resources to many animals in the hot, dry summer, when other plants have little to offer. At that time of year, it seems that every other **saguaro** is topped by a dove, its face spotted with pollen or smeared red with fruit pulp.

By analyzing carbon and hydrogen isotope ratios in the birds' tissues, Wolf and Martinez del Rio will track nutrient flux from **saguaro** to dove and determine the importance of **saguaro** resources in the dove's diet. Isotopes will also allow them to "match" wintering doves in Mexico to breeding populations in Texas or Arizona and thus determine the birds' migratory routes. (Texas birds feed largely on grain from plants that use a C4 photosynthetic pathway, whereas Arizona birds feast on **saguaro**s with crassulacean acid metabolism [CAM] photosynthesis; the different diets result in distinct isotopic signatures.)

The Arizona doves are not only pollinators and seed dispersers for **saguaro**s but also provide food for humans, who hunt them on both sides of the border. Throughout this century, dove populations have been on a roller-coaster ride, responding to changes in hunting intensity, agricultural land use, and destruction of the riparian mesquite woodlands where they once nested in colonies, Martinez del Rio says. Since 1968, Arizona's dove population has decreased exponentially.

Even a well-studied topic like the biology of monarchs can continue to produce surprises, despite years of research. Lincoln Brower, of Sweet Briar College, in Sweet Briar, Virginia, and other scientists have intensively studied these butterflies and found that they migrate across North America over the course of several successive generations. And for half a century, butterfly enthusiasts in groups such as Monarch Watch have tagged thousands of individuals in programs to study migration. Yet after all this effort, biologist and Xerces Society founder Robert Michael Pyle has now found information that redraws the migration picture: Monarchs west of the Rockies do not all winter in California, as had previously been thought. Instead, many cross the Rockies to join the gigantic roosts in central Mexico.

Pyle spent a season traveling south with butterflies and documenting their movements - an effort he describes in a new book, *Chasing Monarchs: Migrating With the Butterflies of Passage*. His observations argue against what he calls the "Berlin Wall model" of monarch migration - that eastern and western populations never cross the Rockies to mix. Brower says Pyle's findings raise the possibility that California roosts may rely on periodic recolonization from Mexican populations - a scenario that has significant conservation implications.

The mind-boggling winter roosts - where millions of monarch butterflies cling to fir trees in dense blankets in a few valleys

in central Mexico - are both an astounding spectacle and a vulnerable phenomenon. Deforestation for agriculture is encroaching quickly, and although some roosting areas have been protected by government decree, Roberto Solis Calderon, of the Mexico Secretariat of Environment, Natural Resources, and Fisheries, remarks that "the first problem we have with conserving monarchs is that they don't pay attention to the decrees." They move from site to site between years, and the number of potential roosting sites is rapidly shrinking.

Although it is widely agreed that conservation of winter roosts is essential, Brower and Pyle argue that threats during migration in the United States may be taking a greater toll on monarch populations than is generally appreciated. In particular, they say, herbicide use on Midwest farmland destroys many milkweed plants on which monarch larvae grow.

Lesser long-nosed bats are not as well known to the average nature buff as monarchs, but they play an important role in southwestern ecology, serving as pollinators and seed dispersers for such plants as agaves and columnar cacti. Theodore Fleming, of the University of Miami, has used mitochondrial DNA and stable isotope analysis as well as field-based studies to study the bats' diet, migration, and mutualistic relationships. Female bats from west-central Mexico fly north 1500 kilometers or more each summer to give birth in communal cave roosts in areas with high protein resources. Carbon isotope analysis indicated that bats feed on flowers of CAM plants such as agaves and cacti in the north and in summer, whereas bats in the south and in winter feed on both CAM and C3 plants.

The isotopic data support the idea that bats time their migration to coincide with flowering schedules of plants along the corridor. DNA analyses confirm that female bats migrate from Jalisco, Mexico, to Arizona, Sonora, and Baja California. "These two kinds of studies are complementary, and together they are very informative in tracking movements," Fleming says. Meanwhile, in the Sierra Madre Oriental, isotope studies by Arnulfo Moreno, of Texas A & M University, indicate that greater long-nosed bats (*Leptonycteris nivalis*) make similar diet switches but rely more heavily on CAM plants. His data from nitrogen isotope analysis hint that migration periods may be physiologically stressful on these animals.

Fleming and Moreno are concerned that clearing of native flora for farming and ranching will fragment migration corridors to such an extent that bats won't be able to travel the distance between habitat islands. Fleming's energetics studies suggest that 100,000 bats migrating from Jalisco to Sonora require 16.6 million cactus flowers. But surveys and data from geographic information system work showing vast conversion to agriculture along this stretch of land suggest that the commuting distance between resource islands is becoming prohibitively long and energetically expensive. Such island hopping makes migration "a very weak link in the annual biology of these bats," says Fleming, who says it argues for "conservation of habitats over large portions of west Mexico."

From knowledge to action

Research on the four pollinator species should greatly augment knowledge of their biology and conservation needs. Such studies are a major step toward understanding the pollination systems of which they are a part although only one step, because the complexity of species interactions such as pollination makes them notoriously difficult to study. For instance, not every animal visiting a flower pollinates it; moreover, pollinators vary greatly in effectiveness, and researchers must quantify effectiveness empirically. In addition, few pollination relationships are cases of one-to-one mutual co-dependence; instead, most involve multiple partners on both sides, whose importance may vary tremendously with ecological context. If a plant loses a pollinator, it may be in big trouble - or it may be unaffected if the original pollinator's place is taken by another pollinator.

Indeed, says Judith L. Bronstein, of the University of Arizona, over evolutionary time, species interactions may experience a great deal of environmental variability - change that most mutualisms seem able to tolerate. Because environments are naturally variable through time, Bronstein says, when judging the vulnerability of a pollination system to human threats one needs to ask "whether anthropogenic change is taking species and interactions beyond the range of what they've evolved to cope with."

The experiments needed to address these questions are often time-consuming and labor-intensive. In the case of the long-nosed bats, Exequiel Ezcurra, of the San Diego Natural History Museum, has confirmed that loss of bats will have detrimental effects on plants that they visit, despite the presence of pollinating moths. His research on agave pollination in Mexico's Tehuacan Valley shows that "the fitness of the plant is substantially reduced [in years] when bats fail to arrive" at the right time. Such studies of the degree of obligacy of relationships are generally needed before one can safely predict, for any given system, whether or not loss of one species will result in "coextinction" of its pollination partner or in a cascade of extinctions.

But although pollination biologists like Bronstein and Carol A. Kearns of the University of Colorado-Boulder call for more basic research, they also urge conservation action based on what scientists already know. As Kearns puts it, "our knowledge of pollination interactions, especially by invertebrate pollinators, is in its infancy, [but] our known losses are dramatic enough to warn us of a potential pollination crisis affecting far more species." Indeed, those concerned with the viability of pollination systems are confronted with conservation biology's omnipresent dilemma - that basic science can never supply all the answers with complete certainty, yet perceived needs for action are pressing enough that at some point, action must be taken on the basis of imperfect knowledge.

Conservation in practice

Although research is a key component of the migratory pollinators project, the biologists taking part in the project feel that

success rests on the use of scientific information to achieve practical goals in preservation, restoration, education, and involvement of local communities in management. Such goals include establishing locally based land trusts in key stopover areas; planting plants critical to pollinators, such as agaves, cacti, and milkweeds; facilitating international scholarly exchanges; reducing pesticide use; and establishing government subsidies for farmers, ranchers, and landowners willing to undertake ecological restoration projects.

As for land preservation, Burquez laments that Sonoran preserves lack connectivity and do not exist in areas of highest biodiversity. Ezcurra commends the Mexican government for setting aside large areas near the border, but he asserts that more preservation is needed and that protection on paper must be backed by enforcement on the ground. He admits to anguish over prospects for conservation, because 95 percent of land in migratory corridors is owned by private individuals or ejidos (collective farms). Ezcurra sees little hope for safeguarding corridors by land preservation alone, stressing that ecologists must think creatively and find ways to work with farmers to achieve conservation goals.

Several concrete actions have already been taken. In addition to the bat conservation work of PCMM (see box page 860), two programs have involved local communities in conservation efforts. On land of the Seri people in Sonora, Nabhan and Calder are training Seri youths as "paraecologists" - amateur experts in ecological research. These trainees will band hummingbirds, map the distribution of hummingbird-pollinated plants, and eventually handle management programs so that the Seri can better protect their land's ecological integrity. As Nabhan puts it, the Seri "are saying, 'We don't just want to be baggage carriers and boat handlers for outside scientists. We want our own traditional knowledge and that of Western science to work together. We want to be full participants.'"

In Jalisco, Nabhan and others have persuaded commercial growers of agaves for tequila production to agree to "pollinator-friendly" harvesting strategies. With post-NAFTA Mexican agriculture becoming large-scale and intensive, and Americans deepening their love affair with the margarita, Nabhan says plantations of tequila agaves have tripled in extent, wiping out habitat for wild agaves. The domesticated agaves are harvested before flowering, thereby threatening bats and other pollinators that feed on agave blooms. But now some Mexican growers have agreed to restore wild agaves and allow some domesticated ones to flower.

While such local conservation efforts get underway and research on pollinators continues to yield new information, Buchmann and Nabhan's multimedia Forgotten Pollinators campaign keeps on rolling, with translations of The Forgotten Pollinators into Spanish and Japanese due out this year and a major television special on pollination to be aired by Turner Broadcasting in spring 2000.

Pollination conservation is progressing on other fronts as well. Gabriela Chavarria, of the public/private National Fish and Wildlife Foundation, is pushing for pollinators to become an important part of Foundation initiatives, and cites 85 pilot projects of the Foundation now doing pollination-related work in the United States and Latin America. And at least three different pollination conservation workshops were held this fall, sponsored by the Union of Concerned Scientists, the Ecological Society of America, and the National Science Foundation. With the migration of pollination to the forefront of the conservation biology agenda, migratory pollinators are forgotten no longer.

RELATED ARTICLE: Migratory pollinators project support

Funding for the migratory pollinators project comes largely from Ted Turner's Turner Foundation and its sister organization, the Turner Endangered Species Fund. According to the Fund's executive director, Mike Phillips, Turner's interest in pollinator conservation began when he noticed a lack of bees on flowers at his Avalon Plantation in Florida. After reading The Forgotten Pollinators, Turner and his staff approached authors Gary Paul Nabhan and Stephen L. Buchmann. Phillips says the Turner team was intrigued by the project's breadth, seeing in it "a grand opportunity to implement conservation over a landscape scale . . . and those opportunities aren't that common."

Project participants hope to influence government policy in both the United States and Mexico, and indeed, US Department of the Interior (DOI) representatives conveyed enthusiasm for pollination conservation measures at the Tucson conference. Like Turner, Interior Secretary Bruce Babbitt had read The Forgotten Pollinators, after which he gathered Buchmann, Nabhan, and other pollination experts together with high-level federal officials. A subsequent DOI roundtable meeting urged increasing research and education, establishing "pollinator-friendly mowing regimes" on federal lands, and encouraging the golf industry to create environmentally friendly golf courses via reduced pesticide use and other measures. And at a workshop this past spring, The US Department of Agriculture, the US Geological Survey, and DOI representatives developed joint research strategies and budget initiatives for pollination conservation. - JW

RELATED ARTICLE: Bat conservation and PCMM

Action is better than talk, conservation biologists agree. And if you're looking to act, it's good to have models on which to base your efforts. The Programa para la Conservacion de Murcielagos Migratorios (PCMM; Conservation Program for Migratory Bats) provides a model for the mix of research, education, and conservation that the migratory pollinators project aims for. In the 4 years since it was established, this affiliation of researchers and environmental educators has achieved impressive success with coordinator and Universidad Nacional Autonoma de Mexico professor Rodrigo Medellin's three-pronged strategy to conduct research on bats, educate the public on their biology, and implement preservation measures.

Currently, 11 research teams work in 21 localities in 12 Mexican states. Most studies focus on three species - lesser and

greater long-nosed bats (*Leptonycteris curasoae* and *Leptonycteris nivalis*) and the Mexican freetail bat (*Tadarida brasiliensis*) - but research at some sites deals with the entire bat community (up to 14 species per site). The teams conduct independent work but collaborate in gathering standardized baseline data on population status, reproduction, diet, and migration biology.

But research is just the tip of the iceberg. PCMM also seeks to protect important roost sites. In Mexico, the occurrence of vampire bats has led to frequent vandalism of roost caves and wanton destruction (often with dynamite) of bats assumed to be vampires. Although vampire bats are usually a nuisance only to cattle, from which they suck blood, when there's a perceived problem people generally "go to the cave with the largest number of bats and kill them" Medellin says. However, since vampires don't roost in large groups in caves, when people target a conspicuous cave roost for destruction, he says, "90 percent of the time they kill the wrong bats."

PCMM's strategy is to mobilize people to protect roosts near where they live. After selecting high-priority caves, PCMM staff conduct environmental education in local communities and work with or help establish citizen groups to protect bat roosts. PCMM helps local groups design management plans, and has helped establish interpretive trails, ecotourism facilities, and even local production of bat-based arts and crafts.

Although protection is a high priority of PCMM, land acquisition is not. Because of their small size, Medellin says, "bat caves are a natural candidate for sanctuary status, and by protecting a small area you're protecting a large portion of the population." However, he adds, "it's not our interest or goal to become stewards of the caves," but rather to advise local groups in being stewards. So far, PCMM has trained dozens of stewards and has reduced vandalism, leading to increased bat populations (including a tenfold increase at one cave). The locally based strategy has also produced some pleasant surprises. On one recent visit to a PCMM cave in Michoacan, Medellin was stopped by local stewards who - unaware who he was - proceeded to tell him all about bats, their conservation, and the wonderful PCMM program.

PCMM's environmental educators work closely with schoolchildren living near bat caves. They begin by engaging them in role-playing games designed to illustrate ecological principles, continue by telling stories, and finish by presenting children's books written and illustrated by the staff. The books are tailored to the particular community and are "very closely tied to the person-to-person environmental education effort," Medellin explains. The approach has paid off. The program has reached over 1000 children at 15 rural schools, and tests have shown a 70 percent retention rate of knowledge after one year. PCMM has also reached several thousand adults through its general education program and has aired radio programs both locally and nationally. Its office is typically flooded with phone calls after each broadcast, overwhelming the capacity of its small staff. "It's amazing, the impact we've been having," Medellin says, "the willingness of people for bat conservation in Mexico."

And PCMM's impact reaches beyond Mexico. Not only is it influencing the direction of the migratory pollinators project, but it has already spawned copycat (copybat?) groups in Bolivia, Brazil, and Venezuela. - JW

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LANGUAGE: ENGLISH

IAC-CREATE-DATE: December 2, 1999

LOAD-DATE: December 03, 1999
