Diseases of Beneficial Insects

Recent reports of the disappearance of honey bees attributed to a mysterious disease called “colony collapse disorder” have brought many issues to the public eye concerning, among others, the importance of beneficial insects, the global movement of both insects and their diseases, and the impacts of species loss on human activities and health. Not all insects are pests, nor are all diseases detrimental—many disease organisms are used in control of pests and all are part of the natural cycle of animals. But diseases in insects we depend upon are not always well understood and may be devastating to agriculture and the natural environment.

Honey bees are the most easily manipulated of the world’s pollinating species and, therefore, the most intensively studied. Even with an extensive knowledge base concerning their pathogen/parasite complex, researchers and producers still are faced with unexpected epizootics and introductions, and the bee industry is constantly focused on identifying, treating, and avoiding various natural enemies that threaten its livelihood. For example, in addition to the recent colony collapse disorder and varroa mite infestations, a microsporidian pathogen, Nosema ceranae, previously thought to occur only in the Asian honey bee, Apis cerana, has now been found to occur worldwide in colonies of Apis mellifera, the European honey bee.

Like all other animals and plants, insects are victims of many different types of diseases—viruses, bacteria, fungi, protozoa, and nematodes. Disease organisms of any or all of these groups are found in any well-studied host species. Like other natural enemies, diseases are important in maintaining insect populations at levels that are actually optimal for the species, preventing populations from outstripping their own food supplies. In terms of human interactions with insects, we would be much worse off if insects such as mosquitoes, blackflies, house flies, and agricultural pests did not succumb regularly and in great numbers to diseases. There are, however, insects such as bees and silk worms, predatory flies and beetles, and other managed beneficial insects that benefit humans, and there may be serious consequences when they are devastated by epizootic diseases.

The Insect Pathology program at the Illinois Natural History Survey partners with federal, state, and university cooperators to study diseases of both pest and beneficial insects. Some of the more recent research projects have dealt specifically with beneficial species. One project involves working with the USDA Forest Service to identify and mitigate the occurrence of disease in several species of beneficial beetles that are being used for biological control of the hemlock woolly adelgid. This Asian adelgid pest is devastating populations of eastern and Carolina hemlocks in both horticultural

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Developing a Regional Monitoring Plan for Chicago Wilderness

The Chicago Wilderness consortium is an alliance of more than 200 public and private organizations working to protect, restore, study, and manage the natural ecosystems of the Chicago region; contribute to the conservation of global biodiversity; and enrich local residents’ quality of life. Since its founding more than 10 years ago, the consortium has recognized that monitoring throughout the region is needed to assess the status and trends of natural communities, which cover more than 225,000 acres. Reaching agreement among the consortium members on what should be monitored has proven difficult, however.

About two years ago, Chicago Wilderness asked the Illinois Natural History Survey (INHS), a charter member of the consortium, to coordinate efforts to develop a regional monitoring plan. The survey has a long history of monitoring the natural resources of Illinois. A prime example of the survey’s efforts is the Critical Trends Assessment Program, which has been monitoring trends in major natural communities around the state for more than 10 years. The survey’s charge is to develop a scientifically sound monitoring program that reflects the consortium members’ priorities. This effort has been led by Dr. Geoff Levin, director of the survey’s Division of Biodiversity and Ecological Entomology.

The process of developing a regional monitoring plan began with a two-day workshop that brought together representatives of many of the consortium’s members. Through a series of facilitated discussions and breakout sessions, we agreed that the two major questions to be addressed through monitoring are 1) what is the health of the region’s natural communities and how is that changing over time, and 2) what impact is management having on natural community health. Workshop participants also agreed that all natural communities in the region should be monitored, but that special attention should be given to rare or endangered plant communities and animal species assemblages. In addition, the group recommended that regional monitoring build on monitoring already being undertaken by consortium members, insofar as those efforts can be integrated.

Following the workshop, the survey spent many months interviewing consortium members to determine what monitoring they currently are doing. (This step has focused on terrestrial systems; a separate effort led by the Chicago Wilderness Aquatics Taskforce is looking at aquatic monitoring.) Most monitoring is being done by governmental agencies, especially forest preserve districts, the Illinois Department of Natural Resources, and volunteer groups. A wide
The Changing Illinois Environment: Critical Trends, a state-of-the-environment report published in 1994 by the Illinois Department of Natural Resources concluded that habitats in Illinois were deteriorating as the result of habitat fragmentation and biotic/abiotic stressors. This report recommended that the state begin collecting statewide data on both the current conditions and future trends in these habitats. Since 1997 the scientists of the Critical Trends Assessment Program (CTAP) have undertaken this task.

CTAP is a long-term habitat monitoring program that samples habitats across Illinois. It is sponsored by the Illinois Department of Natural Resources (http://dnr.state.il.us/) and housed at the Illinois Natural History Survey (http://www.inhs.uiuc.edu/). The goal of CTAP is to gather baseline data on the biological health of our forests, wetlands, grasslands, and streams, and to determine how these habitats are changing through time. This information supports efforts to better understand, conserve, restore, and manage Illinois forestlands, wetlands, grasslands, and streams.

Over the last 10 years the program has surveyed 176 grasslands, 175 wetlands, 177 forests, and over 150 streams (Figure 1). We have sampled sites in all 102 Illinois counties, identified over 1,270 species of plants, and found 202 species of birds. The program has produced 31 regional assessments reports for watersheds throughout Illinois to inform local conservation work. These data are increasingly relied upon by public and private institutions throughout Illinois and even across North America to inform their decision making. For example, the CTAP Web site (http://ctap.inhs.uiuc.edu) has received over 1.3 millions hits in only a few years.

CTAP has accumulated the data to quantify the state of natural and semi-natural habitats throughout Illinois; it is now poised to address ecological trends through time—changes in the future.

Some typical questions that can be addressed with these time-series trend data are:

a) How will the arrival of the emerald ash borer affect Illinois forests?

b) What effect is global climate change having on Illinois’s flora and fauna?

c) Which invasive species are most common or problematic, and which are spreading the fastest?

d) Are macroinvertebrates and aquatic life re-colonizing streams with improved water quality?

e) To what extent are oak-hickory forests becoming sugar-maple forests?

f) How are changes in surrounding landuse affecting flora and fauna?

**Critical Trends Assessment Program Fact Sheet**

- We have randomly sampled forests, streams, wetlands, and grasslands for the past 10 years throughout Illinois (Figure 1).
- 176 grasslands surveyed (14 considered high quality for plants)
- 175 wetlands surveyed (23 considered high quality for plants)
- 177 forests surveyed (24 considered high quality for plants)
- 150 streams surveyed (30 considered high quality)

- Sites in all 102 Illinois Counties (Lake County has the most sites with 22)
- Of the 528 sites we have surveyed 401 were privately owned and 127 were publicly owned

- 1,270 plant species have been identified (1035 native and 235 introduced species)
  - 241 "sensitive" species
  - 42 "problematic" species
  - 11 state endangered species
  - 3 state threatened species
  - 1 federally endangered

- 202 bird species have been identified
  - 7 state threatened species
  - 18 state endangered species
  - 1 federally threatened species
  - 1 federally endangered species

- Produced 31 watershed assessment reports
- 4 peer-reviewed publications have been produced
- >20 presentations at scientific meetings
- >30 presentations at local meetings
- 1.3 million hits on the CTAP website (http://ctap.inhs.uiuc.edu)

- A conservative estimate of 2,700 people contacted to obtain access to both private and public sites.
- Landowners are provided with a list of bird and plant species found on their properties as well as management and conservation information upon request
- Participated in and trained volunteers for River, Forest, and Prairie watch

- Provided information or advise to numerous organizations
  - U.S. EPA
  - SU - Carbondale
  - Wisconsin DNR
  - Heinz Foundation
  - 3 botanists (G. Carroll-Cunningham, J. Ellis, O. Spyreas)
  - 2 ornithologists (S. Bailey, R. Jack)
  - 1 stream ecologist (Dr. E. DaWalt)
  - 1 coordinator (Dr. J. Ward)

**Figure 1. CTAP Fact Sheet.**
Self-sustainable lake trout, *Salvelinus namaycus*, populations in Lake Michigan are a primary but unmet goal of the fisheries managers in the region. Large numbers of hatchery-origin lake trout are stocked into Lake Michigan every year. Although these fish survive well to adulthood and produce viable eggs, no significant natural recruitment has been recorded. Poor lake trout recruitment in various systems has been linked with insufficient broodstock, diminished spawning habitat, contaminants, predation on eggs and alevins, and nutritional deficiencies. However, no clear cause for lack of natural recruitment has been identified for Lake Michigan lake trout. Nutritional deficiencies associated with inadequate levels of thiamine (vitamin B₁) in the eggs result in high mortalities of yolk sack stages of several salmonid species in the Great Lakes and in the Baltic Sea. Mortality caused by thiamine deficiency, commonly referred to as Early Mortality Syndrome (EMS), is a consequence of high levels of thiaminase, an enzyme degrading thiamine, found in prey fishes such as alewife, *Alosa pseudoharengus*, and rainbow smelt, *Osmerus mordax*. Because alewives are a major component of the lake trout diet in Lake Michigan, we hypothesize that EMS may be a significant bottleneck in the survival of early life stages of this species.

The Illinois Natural History Survey, with collaborators from USGS Great Lakes Science Center and the Ohio State University, is investigating individual variation in thiamine levels in the eggs of Lake Michigan lake trout at the time of spawning (picture). Eggs are fertilized, incubated, and hatched under controlled laboratory conditions. High performance liquid chromatography (HPLC) is used to determine concentrations of vitamin B₁ in the eggs. Finally, we quantify mortality caused by EMS in young lake trout and correlate it with levels of thiamine found in eggs from individual females.

Results to date indicate that egg thiamine concentration varies by an order of magnitude among investigated females. More than 50% of all females sampled produced eggs with free thiamine levels below 0.8 nmol/g. In laboratory experiments, EMS frequency soared dramatically among lake trout offspring hatched from eggs containing free thiamine below this threshold (Figure 1). Post-hatch mortality attributed to EMS occurred between 700 and 900 degree-days, an age at which lake trout offspring are swimming and actively looking for food.

Understanding the potential importance of EMS as a regulator of lake trout reproductive success is critical for the effective management of this native Lake Michigan fish. These findings extend our ability to interpret the role of EMS in the lake trout recruitment dynamics. For instance, the actual number of spawning lake trout needed to generate natural reproduction in Lake Michigan may be underestimated by 50% or more once losses associated with EMS are taken into account. Because of the possible benefits of our findings for managers, it is essential to investigate lakewide variability of thiamine deficiency as well as the importance of EMS compared to other sources of early mortality among Lake Michigan lake trout.

*Sergiusz Czesny, and John M. Dettmers, Division of Ecology and Conservation Sciences; Konrad Dabrowski, The Ohio State University; and Jacques Rinchard, USGS Great Lakes Science Center*
variety of plant and animal groups are being monitored, but most data are being gathered on plant communities and birds. In addition, threatened or endangered plants and animals are being monitored fairly extensively. Unfortunately, integrating much of this information into a regional monitoring effort will not be possible. Protocols vary widely among existing monitoring programs, making it difficult to compare their results. Most monitoring locations are selected to answer specific questions rather than being randomly distributed, or are maintained in a variety of formats, including paper files, making it difficult to bring the data together.

Because regional monitoring of terrestrial ecosystems will have to be based largely on newly collected data, it will be important to focus on efficient approaches. Following discussions with experts from within the survey and meetings with consortium members, tentative agreement has been reached to focus initially on plant communities, birds, and turtles. Other organisms either are extremely difficult to identify accurately or do not provide as much information about general ecosystem health. Randomly selected sites will include both managed and unmanaged sites, allowing assessment of both ecosystem health and management effects. The plan will also recommend that Chicago Wilderness encourage expansion of existing successful programs that monitor butterflies, frogs, and threatened and endangered plants. INHS staff currently are finalizing detailed monitoring protocols, methods for selecting monitoring sites that provide a random and representative sample, and recommendations for data management and analysis. A draft plan will be presented to consortium members at a meeting later this year and then revised in response to their input.

A pilot project to monitor plant communities will take place this summer under the guidance of the Chicago Audubon Society with funding from Chicago Wilderness. Full implementation of regional monitoring is slated to begin in 2008. With guidance from the survey and input from consortium members, Chicago Wilderness will be positioned to provide natural resource managers, politicians, and the public with accurate and reliable information about the health of the Chicago metropolitan region’s natural communities.

Geoffrey A. Levin, Division of Biodiversity and Ecological Entomology

Chicago Wilderness

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g) How can preserves and other open spaces be designed and managed to promote biological health and biodiversity?

h) How do grassland birds benefit from the Conservation Reserve Program and other grassland conservation programs?

In addition to addressing these and other questions, CTAP has initiated the CTAP Science and Ecological Policy series. This is an initiative designed to inform managers, researchers, and property owners using the most up-to-date ecological data we have collected, along with the most current scientific expertise on subjects such as forestry, conservation biology, and wildlife biology as they relate to specific questions and concerns held by Illinois landowners, land managers, and policy-makers. The first issue of CTAP Science and Ecological Policy will be an overview of management, conservation, and land managing practices in Illinois forests.

The first decade of the Critical Trends Assessment Program has produced volumes of data with which to determine the distribution and abundance of plants, birds, and stream invertebrates throughout Illinois. The next 10 years will provide a comparison by which to determine the direction of the Illinois environment. With the creation of the CTAP Science and Ecological Policy series, we hope to use these data to best manage and conserve Illinois’ habitats.

Michael Ward, Division of Ecology and Conservation Sciences
My first encounter with a flying squirrel was as a young child, entertained by the cartoon antics of Rocky the flying squirrel and his pal Bullwinkle the moose. Surely an animal like Rocky couldn’t exist—a squirrel that flies? I would later learn that, yes, there were such things as flying squirrels; I even handled a museum specimen—flattened but soft. As someone who keeps a list of all squirrel species, the flying squirrel has become a nemesis. I was close once when a small group of them were frightened out of a tree occupied by red cockaded woodpeckers, but I was off looking at something else. I reveled in a friend’s tale of how they come to her bird feeders every night at dusk, but there is still no check mark by the flying squirrel for me. This spring during a field trip to the Lost Mound area (the decommissioned Savanna Army Depot) a friend found a walnut with interesting holes. She picked it up from the flotsam of the Mississippi River; the walnut had two sets of evenly spaced elliptical holes. The edges had fine tooth marks. Looking around we found a small stash of holey walnuts buried in an old log. We took several back to the Illinois Natural History Survey and showed them to our mammalogist who exclaimed, “Southern flying squirrel!” I am getting ever closer to seeing this illusive animal!

Illinois has one species of flying squirrel, *Glaucomys volans*, the southern flying squirrel. Its scientific name literally translated means “flying gray mouse.” They inhabit the eastern half of the United States from southeastern Canada to southern peninsular Florida. While they may be found in a variety of habitats, from the dry brush country of eastern Texas to the pinelands of the South, they prefer mature deciduous forests with an abundance of nut producing trees such as oak, hickory, or beech.

Flying squirrels have light, flattened bodies that are 8 to 10 inches long and weigh from 2 to 4 ounces. Their fur, called pelage, ranges in color from steel-gray to gray-brown and is silky and dense. The breast is creamy white. They have enormous dark eyes with brown eye rings that contrast against their gray faces. They have flattened featherlike tails that comprise 40% of their total length. A loose fold of skin extends between the fore- and hindlegs, along both sides of the body. This flap, called the patagium, is unique among North American mammals. By extending their legs and stretching the patagium like an airfoil, the squirrels are capable of graceful glides. Most of their glides are less than 100 feet in distance and the squirrels end up lower than their take-off spot.

Flying squirrels live in nests that are from 15 to 20 feet above ground in cavities such as woodpecker holes. The globular-shaped nest is lined completely with plant fibers such as shredded bark, leaves, and grasses. There is usually more than one nest—primary and secondary—which may be used as feeding stations or retreats. The nests have small entries (1.6 to 2 inches in diameter) to prevent other tree squirrels from using them. Flying squirrels do not defecate in their nests. While the squirrels do not hibernate, they do undergo periods of torpor. Usually in the winter they will huddle with up to 10 to 20 other flying squirrels in order to save energy.

In Illinois mating occurs in late February or early March and again in July with young born from late March to May and in August and September. The number of young varies from two to seven. The newborns are pink and hairless with closed eyes and ears, yet by eight weeks they are adult size and furred. They are able to breed within the next year.

Populations of flying squirrels are affected by the reduction of woodland areas and by the removal of dead trees with woodpecker nest cavities. The main predators of these squirrels are barred and great horned owls, while weasels, raccoons, and black rat snakes may prey on them while in their tree nests.

Flying squirrels easily escape our notice as they are the only nocturnal squirrels in North America. Even though they may be abundant, seeing one is a rare treat. They might easily be mistaken for a falling leaf. A comment by two biologists in 1911 gives credence to their common names of “fairy diddle” and “goblins of the night.”

“There is something ghostlike in this gliding flight... There is not only an entire absence of fluttering wings but perfect silence.”

INHS mammalogist Joe Merritt is gratefully acknowledged for providing insights and information about southern flying squirrels for this article.
Looking for Signs

It is common for animals to be present in an area without being noticed. Flying squirrels, for instance, are nocturnal and are seldom witnessed by people who only frequent these areas during the daytime. Many animals are very secretive and stay quiet and hidden when people are present. Many of these animals do, however, leave signs that they were there. You may find tracks, scat, debris from feeding, burrows, cast skins, and other signs. See if you can match up the signs with the correct animal.

When you are out in a natural area, look for these signs and study them. Photograph or sketch them, and then look in field guides to see if you can determine who left the clue to their activity.

1. southern flying squirrel _________ (walnuts with smooth hole)
2. beaver _________ (chewed tree trunks)
3. Pileated Woodpecker _________ (rectangular holes in tree trunk)
4. crayfish _________ (mud chimney)
5. Yellow-bellied Sapsucker _________ (small holes drilled in straight lines)
6. leafcutter bees _________ (round holes cut from leaf)
7. cicada _________ (empty skins of immature insects)
8. insect galls _________ (bulbous growth on twig or leaf)

All photos by Michael Jeffords (INHS) except the shot of Yellow-bellied Sapsucker holes, which was taken by Kelly Cook of INHS
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and natural environments, including old-growth trees in pristine forest areas. Three of the beetle species being used in the adelgid biological control programs have been found to harbor microsporidia, fungal-like pathogens that insidiously infect the insects and cause shorter adult lifespans, larval death, and lowered egg production. The microsporidia can build up in the laboratory colonies and cause death of a large percentage of colony insects that have been painstakingly reared for biological control projects. We are currently identifying these microsporidia and learning about how they infect and are spread.

The most recent project, a collaboration between the authors at INHS and the University of Illinois and Jamie Strange and Terry Griswold at the USDA Bee Biology and Systematics Lab in Logan, Utah, addresses the potential causes of population declines of some of our most important native plant pollinators, the bumble bees. There are more than 50 species of bumble bees (Genus Bombus) in North America and several appear to be declining severely. Our team will approach the problem of identifying the reasons for decline by addressing two of the myriad potential causes—the isolation and fragmentation of bumble bee populations and the occurrence of diseases that might be invading North America, or are native but with effects that may be exacerbated by other pressures. Supported by a grant from the USDA National Research Initiative, we will compare historical information from museums and the scientific literature with the current ranges of six species of bees and their parasites and pathogens.

We have, in preliminary studies, identified several pathogens and parasites isolated from bumble bees collected in the American West and Midwest. Individual bees from two populations in Illinois, as well as bees from western populations, were infected with a pathogen, a microsporidium, that is a genetic match for a species that occurs in European bumble bees. We will be working to determine whether this pathogen is a recent invader that has spread across the continent or is found globally in bumble bees. Illinois residents can help by informing us about areas, particularly fields and natural areas, where bumble bees are frequent visitors so that we can sample the populations.

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