Learning from Naturally Occurring Epizootics in Insects

Stands of eastern hemlock, *Tsuga canadensis* (L.) Carrière, are facing an alarming decline. Two invasive insects, the elongate hemlock scale, *Fiorinia externa*, (Fig. 1), and the hemlock woolly adelgid, *Adelges tsugae*, have been identified as primary causes in the decline. Control efforts have focused mainly on *A. tsugae*. However, the rapid geographic expansion of the scale in the last 20 years (present and/or established in all eastern coast states from southern New England to western Ohio and Tennessee) has raised public awareness and concern for the potential impact of this species. If dispersal of both pests continues unimpeded, drastic changes in forest tree composition will follow. Hemlocks play a particularly important ecological role along streams, where their shade provides shelter, sustains aquatic ecosystems, and creates a unique microclimate for forest wildlife. As hemlock trees decline in vigor, openings in the canopy allow an increase in understory light levels. As a result, hardwood species especially black birch (*Betula lenta* L.) establish, leading to major landscape changes by transforming large areas dominated by conifers to young, rapidly growing hardwoods.

In 2001, an epizootic (outbreak of disease in animals) was detected in *F. externa* populations in the hemlock forest at the Mianus River Gorge Preserve in Bedford, New York. Large sclerotia masses (compact mass of fungal mycelium) were found in mumfied specimens concealing in many cases the body of the adult (Fig. 2, back page).

We found that up to 36.8% of the sampled populations were partially or completely covered with sclerotia. A fungus was the most commonly retrieved pathogen in 36 sites from New York, Pennsylvania, Connecticut, and New Jersey, suggesting it might play a key role in the epizootic.

The fungus retrieved from wild infected *F. externa* was successfully inoculated into uninfected laboratory populations of this host and subsequently recovered from dead scales, after surface sterilization. DNA was extracted from our unknown fungus, and an array of nuclear genes were sequenced.
Climate Change and Biodiversity

(The following article is excerpted from the Winter 2009/Spring 2010 issue of Illinois Steward magazine with the kind permission of Robert Reber, editor.)

Photos by Michael R. Jeffords.

When I came to Illinois in 1985, there was consensus that the greatest threat to fish, wildlife, and flora was habitat loss. Illinois was last or near last in the nation in public open space per capita; and 79.9% of Illinois was plowed, paved, drained, or landscaped. Over the next decade, with the rise of globalization, the onslaught of invasive species would quicken, until in 2005 it was estimated that invasive alien species in the United States caused environmental damages and losses of almost $12 billion per year. There were approximately 50,000 foreign invasive species on U.S.-controlled soil, and about 42% of the species on various state and federal threatened or endangered species lists were at risk primarily because of invasive alien species.

Climate change is perhaps the most insidious of the threats to biodiversity because its impacts will be felt by species, and it will be difficult to identify conclusively the decline of a particular species as climate-related without eliminating many other potential causes. In short, our native biota could fall victim to a proverbial “triple whammy.”

Our Climate Is Changing

I have found it frustrating to endure over a decade of debate about whether climate change was “real.” Even if you do not believe that climate change is human induced, our climate is changing; and as a result of habitat loss and the fragmentation of our remaining habitats, our native plants and animals are less able to “adapt” to this change than they might have been in the historic landscape.

It Will Become Warmer and Rain Harder in Illinois

The Illinois State Water Survey (ISWS) is a recognized international leader in climate modeling. It has developed a Regional Climate Model that does a much better job of predicting historic climate than some of the global models relied upon by other parts of the country. Recent national study in which the ISWS participated suggests that while the average precipitation may not have increased significantly, the intensity of precipitation across the eastern United States has been increasing over the last century.

Monitoring Is the First Line of Defense

Illinois is one of the few states in the nation that has a statewide monitoring program across a broad spectrum of habitat types (forests, woodlands, savannas, prairies, and wetlands)—the Critical Trends Assessment Project (CTAP) established in 1997. The Illinois Department of Natural Resources has had the foresight to continue funding this program; and now with the recognition of climate change as a major threat to biodiversity, CTAP data have become invaluable.

Another long-term study being conducted by the Illinois Natural History Survey, The Nature Conservancy, and the Department of Natural Resources and Environmental Sciences at the U of I is the 100-Year Bird Survey, which is re-surveying the birds present at sites originally investigated in 1906 and again in 1956. These data suggest thatkill-deers have increased in numbers and that cardinals and red-bellied woodpeckers have expanded their ranges during the past century. One might hypothesize the range expansions were related to climatic warming; but they are also forest birds, and the acreage of forests in northern Illinois also increased during this period. Both are also species that are becoming adapted to living in suburban settings, which could also have contributed to their range expansions in concert with increasing suburban areas.

The Most Vulnerable Threatened and Endangered Species: The species that will be most vulnerable to the impacts of climate change will be those species that have already been threatened or endangered. With the threat of climate impacts, it is imperative to monitor those species that have the fewest occurrences, the least capacity to migrate to new habitats, and occur in communities that could not support those species living there now.

Extreme habitats such as sand prairies and glades can become too hot to support the species living there now.

Headwater Streams and Shallow Streams: Headwater streams and streams small enough to wade, along with the fish and invertebrates that live in them, could be extremely vulnerable to climate change. It is critically important to characterize the species living in headwater and shallow streams now, to establish a baseline for assessing the impacts of climate change on them in the future. A statewide survey of wadeable streams should be begun as soon as possible.

Small streams are sensitive to warming temperatures.

Small high-quality natural communities such as Loda Cemetery Prairie Nature Preserve could lose less common species as a result of a changing climate. When species with critical management needs are identified but we do not currently have a management response, such cases will have to be turned over to teams of specialists for further diagnosis, the conservation community’s version of television’s “House.”

While the “triple whammy” is a formidable opponent, I remain optimistic that our natural resource scientists and natural resource managers will meet the challenges ahead if we provide them the needed resources. They have an admirable record!
Lake trout (Salvelinus namaycush) is a cold water predatory species, native to North America including the Great Lakes. It thrives in oligotrophic, oxygen-rich waters, where it grows fairly slowly and matures relatively late (at age 5-6). Due to these characteristics, lake trout populations are susceptible to overexploitation. Historically, lake trout was the dominant predator throughout the Great Lakes. However, by the mid-1950s, this native fish was nearly extirpated from Lake Michigan due to a combination of commercial overfishing and sea lamprey (Petromyzon marinus) predation. Lake trout were returned to Lake Michigan with the advent of a sea lamprey control program administered by the Great Lakes Fishery Commission and intensive federal stocking efforts, which began in 1965. Since that time, spawning aggregations of stocked lake trout, fertilized eggs, and lake trout fry have been observed in Lake Michigan, but evidence of naturally produced (wild) adult lake trout remains rare. Thus far, restoration efforts have been largely unsuccessful at developing a sustainable, naturally reproducing lake trout population in Lake Michigan.

Contemporary lake trout restoration efforts are focused on promoting natural reproduction and the protection and restoration of critical habitat. The quantity and quality of spawning habitats are a vital determinant of spawner selection and egg/embryo survival. Recent work on the mid-lake reefs, an area known to attract lake trout in northern Lake Michigan during the spawning season, reported the presence of lake trout eggs on areas characterized by strong vertical relief and complex cobble substrate. Intertidal spaces at least 20 cm deep within cobble/robble substrate are thought to afford lake trout eggs and fry some degree of protection from predators. Although a significant amount of research on lake trout spawning aggregations and habitat suitability has been conducted in northern Lake Michigan, offshore reefs in the southern basin are poorly described. Two bedrock reefs off the Illinois Lake Michigan shoreline, Julian’s and Waukegan Reefs, are part of an extensive complex of bedrock highs exposed on the Lake Michigan lakebed and are believed to provide spawning habitat for lake trout (Fig. 1). Illinois Department of Natural Resources (IDNR) sampling shows that large numbers of lake trout aggregate at these reefs during spawning season, but there are no detailed maps of these reefs and no recent information on egg deposition.

During 2009, researchers from the Illinois Natural History Survey (INHS) Lake Michigan Biological Station along with collaborators from Habitat Solutions, Inc. used sidescan sonar and underwater video to develop substrate maps for Julian’s and Waukegan Reefs and identify potential lake trout spawning habitat. The project team covered 10 km² of lakebed from the Waukegan Reef complex and 7.2 km² of lakebed from Julian’s Reef. Multiple previously unknown bedrock areas were detected south of the area originally associated with Waukegan Reef (Fig. 2). The discovery of these bedrock areas indicates the area of potential spawning habitat may be greater than anticipated and shows a lack of adequate information regarding habitat and substrate characteristics within southwestern Lake Michigan.

Numerous areas over Julian’s and Waukegan Reefs were identified as potential lake trout spawning habitat due to the presence of coarse cobble-boulder substrates (Fig. 3). These areas were targeted with deep-water egg traps during the 2009 spawning season, but no intact eggs or egg chorions were found at either reef. The project team plans to evaluate the bathymetry (laked bed relief) of both reef complexes during 2010. Integration of fine-scale bathymetric data with existing substrate maps will allow identification of areas with both significant vertical relief and cobble substrate and lead to a more accurate evaluation of egg deposition during the 2010 spawning season.
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During a late February evening I was driving to a frog monitor out of the car, hurrying from snow bank to snow bank—a mink! Wow, a wildlife encounter beats a frog call any day! Why wasn’t it hibernating and what was it doing? Time to pester one of my favorite Illinois Natural History Survey mammalogists, Joe Merritt, author of *The Biology of Small Mammals*, to find out more about mink.

**Minks** *(Mustela vison)* are never found far from fresh water and occur throughout the United States, with the exception of the Southwest, which is too dry for their needs. In Illinois they may be found along the banks of drainage ditches and streams or the marshy shores of ponds and lakes where there is suitable cover and food resources. An abundance of minks is directly correlated with large populations of muskrats, upon which the mink prey.

As members of the weasel family—the Mustelidae—they are related to badgers, otters, and weasels. This family is the largest in the mammal order Carnivora. They share several characteristics with other weasels, including a flexible backbone, which permits them to arch their backs while bounding. They have small, flattened heads and short sturdy legs. They differ from other members of the genus *Mustela* (long-tail and least weasels), in Illinois, as minks are larger, have bushier tails, and longer hind feet. Their under and upper parts are nearly the same color, rather than white or white with an orange wash. Minks are found in aquatic habitats, and unlike weasels, minks do not turn white in the winter.

Minks, who are excellent swimmers, are specialized for an aquatic life and seldom wander far from water. Their toes are connected with webs at their bases. They have bushy tails and small ears that barely project above their fur. Their water repellent fur is a dark chocolate brown and is lighter on the bottom than the top.

With poor eyesight and hearing, they must rely on their keen sense of smell to locate prey. Their prey includes muskrat, fish, cottontail, crayfish, waterfowl, amphibians and reptiles, and insects. Usually they feed and hunt at night. To subdue the prey they inflict a series of fatal bites to the neck and base of skull. Their diet varies, depending on the availability of food items at different times of the year. As minks are active year-round, they will cache prey for the winter. Minks are solitary except during the mating season and while the young are with the mother. Minks will mate from January to March, and during the delayed implantation of the embryos, young are not born until April or May. A litter consists of three to six hairless, pink kits (young). They quickly grow fur and their eyes will open in about three weeks. They will be weaned between 1.5 and 2 months, and by 10 months the kits are sexually mature.

Mink dens are usually near the water, and may be in hollow logs, under stumps or tree roots, in rock piles, or a burrow in the bank. The dens are located one to three feet below ground and have several entrances. While great horned owls, foxes, coyotes, and bobcats will occasionally prey on minks, humans are their principal predators. Trapping takes its toll, but habitat destruction and drainage of wetlands are also factors.

**Recommended Reference:** *Field Manual of Illinois Mammals*, by Joyce E. Hofmann

**Photos:**

Philip Nixon (bobcat, black bear, wolverine, badger, harbor seal, sea otter)

Carolyn Nixon (raccoon, mink)

Michael Jeffords (coyote, river otter)

Riversdeep Interactive Learning Limited (mountain lion, polar bear, wolf) (© 2010. Riversdeep Interactive Learning Limited, and its licensors. All rights reserved.)

John James Audubon (painting of fish)
Epizootics continued from front page

DNA sequences from our unknown pathogen showed a high degree of similarity to those originating from a fungus in the genus *Colletotrichum*. How could this plant fungus infect an insect? A hard look at the literature uncovered a previous report of pathogenicity in insects from a fungus in the genus *Colletotrichum*.

We named the unknown epizootic-causing organism, *Colletotrichum acutatum* var. *fioriniae* var. nov., to indicate that it is similar to *Colletotrichum acutatum* but differing in its pathogenicity on *Fiorinia externa* (Fig. 3).

We molecularly documented the ubiquitous occurrence within epizootic areas of *C. a. fioriniae*, growing as a nonpathogenic endophyte in 28 plant species (i.e., no signs or symptoms of disease in the host). This was confirmed in laboratory plant trials with various species of plants showing no external symptoms or signs of infection (reported in some entophytic strains in this genus), in opposition to the necrotrophic (intracellular colonization of the fungus in the host causing necrosis) growth in *F. externa*. *C. acutatum* has been shown to inhabit different niches. It has been hypothesized that these may be specialized monomorphic groups that constitute distinct lineages.

Our research showed that genetic variation in the fungus *Colletotrichum* may give rise to new biotypes with a propensity to infect insects. The conidial anastomoses (fusion of conidia or conidial germ tubes) between isolates of two different *Colletotrichum* species, *C. lindemuthianum* and *C. gossypii*, have been previously reported. Anastomosis can facilitate the exchange of genetic material between members of the same as well as different species, giving rise to hybrids with new characteristics. *C. a. fioriniae* displays the unusual characteristic of being able to infect animal tissue, a drastic change from the common phytopathogenicity of the genus, representing an inter-kingdom host shift, previously reported once for the genus *Cordyceps*.

Jose Marcelino, University of the Azores, Portugal and Rosanna Giordano, Illinois Natural History Survey

Figure 2. Sclerotic masses in mummified scale insect from an epizootic area.

Figure 3. Phenotypic plasticity of *C. acutatum fioriniae* multispored cultures (A) and single spored cultures (B). No contaminant was detected after microscopic analysis.