Learning from the Flood of 1993

Although the Flood of 1993 was a $12 billion economic disaster, it was also a once-in-a-lifetime opportunity for Natural History Survey researchers to study the dynamics of large-river ecosystems. Among the Survey workers who monitored the flood and its effects on plants and animals were Charles Theiling and his staff at the Long Term Resource Monitoring Station on the Upper Mississippi River at West Alton, Missouri. They continued to work from their homes after their field station was destroyed by flood waters. Staff at the Survey’s research station on the Illinois River at Havana also continued sampling throughout the flooding.

How could the flood possibly be an opportunity? The answer has to do with the nature of field work on large ecosystems. A laboratory scientist can test his or her ideas with carefully controlled experiments, and a field biologist can do likewise in an experimental pond or stream, but a scientist working on a large river usually has to wait for nature to provide the experiment: the strong stimulus that reverberates throughout the ecosystem, affecting the key indicators that are being monitored. The wait can be longer than the scientist’s lifetime. In any given year, the chance of a flood as big as the one in 1993 has been variously estimated as 1 in 100 to as little as 1 in 500.

Important ideas in large-river ecology currently are described in the Floodpulse Concept, developed by Survey aquatic ecologists Peter Bayley and Richard Sparks, in cooperation with Wolfgang Junk at the Max Planck Institute in Germany. If the tenets of this concept are correct, there should be an exceptionally large 1993 year class of fishes (a “year class” is the group produced during a given year) that nest in the shallow margins of the Mississippi River floodplain (including largemouth bass, crappies, and sunfishes) or on flooded vegetation (grass pickerel, for example). Indeed, relatively large numbers of juvenile fish from 52 species and 15 families were collected by Survey researchers during the summer of 1993 on the Mississippi River floodplain near Grafton, suggesting that some fishes extended their spawning season as flooding continued. The flood lasted an unusually long time, cresting four times and falling very slowly, so the juveniles had plenty of time to grow before they had to retreat to the permanent channels and backwaters (see hydrograph, page 2).

Unfortunately for the fish, the Corps of Engineers took the unusual step of lowering the river in November and December be-
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low the minimum level normally maintained for navigation. This drawdown may have forced fish out of favorable wintering areas or stranded them in shallow pools, which could have frozen all the way to the bottom during winter. Fish sampling in 1994 will indicate whether the exceptionally abundant 1993 year class, which could provide large adult fish for several years to come, was drastically reduced by the drawdown.

Water levels were drawn down to assist levee districts that remained flooded because the land suddenly rushes onto the floodplain. A slow, natural rise allows terrestrial animals, such as deer and turkeys, to vacate to higher ground and creates a moving zone of shallow water that advances across the floodplain. In this zone, nutrients can be released from the newly flooded soils, stimulating production of microscopic animals, just when they are needed as food by larval fishes.

Unfortunately, several pest species, including some mosquitoes that are vectors of human disease (see November/December issue of INHS Reports) and the newly introduced zebra mussel (see article on page 3), were aided by the flood. The larvae of several species of mosquitoes do well in temporary pools and in water-filled containers, abandoned tires, and tree holes, where their predators (primarily other insects and fish) cannot enter or survive.

The understory of the floodplain forests has been temporarily eliminated by the protracted flood, and gaps may even open in the canopy as some individual trees that have been weakened by disease. In compensation, the absence of shading and other forms of competition with enable cutoonwoods and perhaps many other species to germinate and grow, thereby rejuvenating mature plant communities. In some places along the Missouri River, the river itself was rejuvenated where it broke levees that are unlikely to be rebuilt (at least in the same place) and scoured new basins and channels to replace those that had been lost to sediment accretion.

The greatest legacy of the flood may be new attitudes and policies regarding floods and floodplain management. Despite the expenditure of billions of dollars on flood protection over the past century, the average annual costs of flood damage have been rising, even when adjusted for inflation. The levees and pumping stations themselves become part of the loss during a major flood and are used to justify increased expenditures on yet higher levees and upstream flood storage reservoirs—a fact that has prompted the White House to reexamine the nation's flood management programs. In a few months, the Interagency Floodplain Management Task Force will make recommendations to the president regarding modification of federal programs to better protect life, property, and Upper Mississippi River ecosystems. The addition of ecosystem protection to the list of goals is based on increasing public and governmental appreciation of the role of natural floodpulses and value of natural services provided by rivers, floodplains, and wetlands. These services include production of fish and wildlife; preservation of biodiversity; water purification; self-repair following natural or human disturbance; and, especially after 1993, the conveyance, storage, and moderation of floods.

Richard Sparks, with information provided by Charles Therling, Robert Maher, and John Nelson, Center for Aquatic Ecology

Changes in the level of the Mississippi River at Grafton, Illinois, during 1993. Average water elevations and levels during drought are shown for comparison. In November and December, the Corps of Engineers reduced the water elevation below the normal level maintained for navigation to help drain water out of breached levee districts.
Zebra Mussels in Rivers

“There is a continuous mat about 2 inches thick on the bottom, and if I dig my fingers underneath, I can lift it up like a carpet,” said Scott Whitney, whose voice came over the speakerphone on the Natural History Survey boat River Diver. Scott—who was 30 feet under water and breathing through an umbilical hose—was describing a layer of zebra mussels at the bottom of the lower Illinois River, near the confluence with the Mississippi, in August 1993.

Scott had found something that was not supposed to happen: zebra mussels had colonized a mud bottom, instead of attaching to rocks, logs, and other solid objects with their sticky byssal threads. Although clumps of zebra mussels the size of baseballs had been observed on mud and sand in the Great Lakes, nothing like this carpet containing up to 94,000 small (½ inch) mussels per square meter had been observed. This was the first documented population explosion of zebra mussels in the Mississippi River drainage.

Water users along the lower Illinois and Mississippi rivers were suddenly scrambling to install chlorine injection devices to kill incoming larvae and adult mussels. Many downstream users had thought the mussels would invade and affect upstream reaches first, gradually progressing downstream from Chicago, where canals link source populations in Lake Michigan to the river (see INHS Reports nos. 298 and 310, June 1990 and October 1991, for more information).

In fact, sampling by Survey staff at five study sites along the Illinois River (see map, page 4) showed that concentrations of zebra mussels in the fall of 1993 were greater downstream than upstream. The average zebra mussel density was 61,000 per square meter at Grafton (at river mile [RM] 5.5, near the confluence with the Mississippi), compared with 1,800 per square meter at Peoria (RM 162.3) and less than 1 per square meter at Chillicothe (RM 181.0). Likewise, whereas 99% of native freshwater mussels at Grafton were infested with zebra mussels, only 3% at Chillicothe were affected.

The most likely explanation for the greater number downstream is that a pulse of zebra mussel larvae from southern Lake Michigan or from the upper river was carried far downstream (perhaps by the Flood of 1993; see related article on page 1) during their 10- to 30-day larval period before they settled on the bottom. Where the mussels eventually settle out is determined by the velocity of the river current and the duration of the larval stage. That the mussels in the lower Illinois River at Meredosia and Grafton came from one pulse was supported by their uniform, small size; practically all were less than 15 millimeters. If the current velocity during the period of larval release is less in 1994 than in 1993, the upper or middle sections of the river could be seeded, so much of the river could become carpeted with zebra mussels in just two years.

What effects will the zebra mussels have in the Illinois River? This is an important question because it portends what could happen to the rest of the Mississippi drainage. Waterway shippers are likely to face rising costs because masses of attached zebra mussels can plug engine cooling systems and increase the water resistance of boat hulls, thereby increasing fuel costs and maintenance costs per mile. Water users will have to install and operate chlorine injection devices to keep zebra mussels from clogging intake pipes; estimated annual costs for chlorine alone are several hundred thousand dollars each for some industries along the Illinois River.

The environmental effects of zebra mussels include direct effects on native species. Zebra mussels threaten native mussels, clams and snails, and the animals that depend upon these native species for food, shelter, or egg-laying sites. Natural History Survey divers have found freshly dead native mussels (with meats inside) so heavily infested with zebra mussels that their shells could not be forced closed. Others were held shut by tufts of
Could zebra mussels at the densities occurring in the lower Illinois River significantly lower oxygen levels in the river? A definitive answer requires intensive field measurements of both zebra mussel populations and oxygen uptake rates, and no such coordinated measurements have been taken. Cursory measurements and back-of-the-envelope calculations indicate that problems are already developing, however. Oxygen levels recorded by Natural History Survey staff and others last fall in the Illinois River near Grafton were well below the Illinois water quality standard for dissolved oxygen and well below the levels recorded in July and August 1991. In most locations, oxygen levels decreased with depth, indicating a strong oxygen demand coming from the bottom where the zebra mussels are. It is possible that receding flood waters carried oxygen-demanding organic matter into the river, but calculations by Survey staff and others indicate that the carpet of zebra mussels also had an effect, which would be even stronger under low-flow conditions, when the waste-diluting capacity and oxygen resources of the river are lowest. With severe depletion of oxygen by zebra mussels, portions of the river could revert to the foul, lifeless condition that occurred just after the turn of the century when excessive organic wastes from Chicago used up all the oxygen for 100 miles downriver.

It may be possible to reduce zebra mussel populations in some rivers without harming native aquatic organisms by focusing on the weak link in the mussel's life history: the larvae. In contrast to the larvae of native mussels, which attach to fish and are carried upstream as well as downstream only. Because zebra mussels live only four or five years, and adults do not move on their own more than a few feet upstream, dense beds of zebra mussels persist only if they are reseeded by larvae from upstream sources. Reduce the upstream supply of larvae and you reduce the downstream populations, perhaps triggering reductions that would cascade downstream. If most of the larvae in the Illinois River come from southern Lake Michigan or the Chicago canal system, the supply could be interrupted by thermal barriers in upstream lock chambers. There is plenty of waste heat from industrial and municipal sources in Chicago, and the heat could be dissipated within the canal system, leaving no residual toxicity, as occurs with chemical agents that must be detoxified. Pleasure boats and the lock mechanisms could benefit from the warm-water treatment, which would kill attached adult mussels as well as any larvae that were in the water, and adult mussels would be less likely to hitchhike to distant parts of the inland navigation system.

Measurements should be taken and predictive models developed as quickly as possible to quantify the effects of zebra mussels more precisely, not just for the sake of the Illinois River but because what happens to the Illinois River is likely to happen elsewhere as well. The place to try out techniques for managing zebra mussels in rivers is the Illinois, where the first documented population explosion in the Mississippi River drainage is well under way.

Richard Sparks, Center for Aquatic Ecology, with information supplied by Thomas Buit, Illinois State Water Survey, and Scott Whitney, Sharak Madon, Douglas Bledgett, and Eric Ratcliff, Center for Aquatic Ecology
Stoneflies of Illinois

Stoneflies are a small, diverse group of insects whose immature stages are entirely aquatic. Some 550 species in 91 genera are known from North America, and eight of the nine North American families are found in Illinois. Stoneflies are well known to fly-fishermen, who frequently tie flies imitating adult or larval features, as depicted in the film *A River Runs Through It.*

Stonefly larvae are an important component of stream ecosystems. Some species are top invertebrate predators, and others feed on coarse particulate organic matter. Many serve as an important food source for other animals. Because stoneflies are intolerant of a variety of environmental perturbations (such as excessive siltation, temperature alterations, and acidification), researchers often use them to monitor the health of aquatic systems.

Most stoneflies complete their life cycle in a single year, but several larger species can take two or more years. Often there is an egg or larval diapause, a period during which growth and development is suspended. Adults are short-lived, surviving only a few days to a few weeks.

Among many stonefly species, individuals drum to find suitable mates. The male beats his abdomen on vegetation, and the female responds in kind, enabling the male to locate the female. Following mating, the female lays her eggs in a stream, where the life cycle begins again.

Twenty species in Illinois emerge as adults during the dead of winter. The presence of these small, black insects during winter has confounded many a naturalist. From November through March, one can easily collect these “winter stoneflies” as they bask in the sunlight on bridges, crawl across stones lining creek shorelines, or hide in dry leaf packs caught in the brush along a brook.

The Natural History Survey has played an important role in stonefly systematics. Theodore H. Frison, the chief of the Survey from 1930 to 1945, authored two Survey bulletins, published in 1929 and 1935, on the stoneflies of Illinois; a third Frison bulletin, published in 1942, summarized much of the knowledge of the North American species. Survey entomologist Herbert H. Ross, with William E. Ricker, provided detailed revisions of important winter stonefly genera in the late 1960s and early 1970s. The thousands of specimens collected by Frison, Ross, and others have given the Survey an exceptional record of species diversity and distribution over time, especially in Illinois.

While examining the Illinois records recently, Survey staff were surprised to find that about 40% of species were collected from three or fewer locations. A study was begun to find out why each of these species was apparently rare in Illinois and to document the current status of the Illinois stonefly fauna in relation to environmental perturbations over the past 50 to 70 years.

Recent collections have yielded some interesting results. For a number of species, the historic and present distributions remain similar; historically abundant species remain abundant, and several species that were previously known from a single locality are still found only at that one location. Some species seem to be more widely distributed today than in the past, but this finding is probably due to undersampling in the past.

Unfortunately, many species, some previously widespread, have not been collected recently.
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Future efforts will concentrate on finding these species. Already there is evidence that some species have been eliminated from the Illinois fauna. Conversely, a few species have been added to the Illinois species list from new collections and from systematic changes.

Survey staff now have records of 65 species of stoneflies in 26 genera from Illinois. Data on Illinois specimens have been entered into a computer database, and work continues on the remainder of the stonefly collection. More than 8,500 records have been entered, including more than 3,200 from Illinois. When all the data are entered, the stoneflies will be the first insect group at the Natural History Survey for which all collection information will be accessible by computer.

Mitchell A. Harris and Donald W. Webb, Center for Biodiversity

More than Prairie Chickens

From the 1860s through the 1950s, the number of prairie chickens in Illinois plummeted because of widespread conversion of prairie to farmland, heavy hunting pressure, and other factors. To help prevent these birds from being eliminated from the state, grassland sanctuaries were established beginning in the early 1960s in Jasper and Marion counties.

These sanctuaries have provided much-needed habitat not only for prairie chickens but also for other grassland species. Within the past five years, in fact, the list of responding grassland birds has grown such that the prairie chicken is no longer the only focus of management and research efforts.

Some of the responding birds are rare species. Among the 12 species of threatened or endangered birds that are year-round residents in Illinois, five are dependent or semidependent on grasslands, and all five are now found on the sanctuaries. In addition to the prairie chicken, these species are the loggerhead shrike, Northern harrier, short-eared owl, and barn owl.

Prairie chickens and loggerhead shrikes were permanent residents when the first sanctuaries were acquired (1962–1964) and seeded to cool-season grasses and forbs. For 20 years, Northern harriers and short-eared owls were observed only as winter foragers. The first harrier nest was found in 1983, and nesting by short ears began with a surge of at least 13 nests in 1990, along with at least eight more harrier nests. There was widespread nesting by both species again in 1993 on the sanctuaries in both Jasper and Marion counties. These nesting concentrations in 1990 and 1993 were the largest known to exist in Illinois. Harrier nesting on sanctuaries has now been documented for five consecutive years.

Although there were no confirmed sightings of barn owls on the sanctuaries from 1962 through 1992, nesting by barn owls began in 1993 in an artificial nest box. Only four other active nest sites were known in the state in 1993.

Sanctuary grasslands provide a vital source of prairie voles, southern bog lemmings, and other prey for these rare harriers and owls. During winter sunsets, possibly 75 or more harriers and 30 short-eared owls can be observed in Jasper County alone—one of the largest concentrations in Illinois. Sometimes a few prairie chickens are included in the mix as they go to roost.

Threatened and endangered birds that are present on the sanctuaries during the spring and summer breeding season have long included upland sandpipers and Henslow’s sparrows. In 1990, two apparently successful nests by king rails provided another first in the database for sanctuary breeders. King rails were officially listed as threat-

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Young Northern harriers in a nest on a prairie chicken sanctuary in Jasper County.
en in Illinois in January 1994. Two other wetland birds, the American bittern and the yellow rail, are recent additions to the list of endangered birds on the prairie chicken sanctuaries, but their secretive behavior coupled with their preference for wetland habitat makes verification of nesting difficult.

Removal of tall wooded fence rows on or bordering sanctuary habitat has created additional, vital open space for threatened and endangered species. Another change, near the Jasper County sanctuaries, was the creation of Newton Lake in 1977 by Central Illinois Public Service Company. Bald eagles, ospreys, and even sandhill cranes (all endangered) can now sometimes be observed in the area. Other, more abundant species have also benefited from these changes in the landscape. For example, mallard nesting, which began on sanctuary grasslands in 1977, is now common.

The Nature Conservancy, the Illinois Department of Conservation, the Natural History Survey, and other organizations have worked cooperatively for three decades to develop the Illinois prairie chicken sanctuaries, as part of broader efforts to preserve the full array of biological diversity in Illinois. Unfortunately, the basic minimum goal of land acquisition for these sanctuaries, 1,500 acres in each of the two counties, is barely two-thirds accomplished. Needed additions to the sanctuaries can now be expected to benefit much more than prairie chickens.

Ronald L. Wessemeier, Center for Wildlife Ecology

Aphids and Crop Disease

Barley yellow dwarf, the most widespread and economically important viral disease of cereals worldwide, can cause major yield losses in the Midwest in epidemic years. This disease affects over 100 species in the grass family, including barley, wheat, oats, sorghum, rye, corn, rice, and a wide variety of wild grasses. It causes stunting and yellowing of plants, with more severe symptoms and greater yield loss the earlier the plants are infected.

The virus that causes barley yellow dwarf cannot be transmitted by seed or mechanical means but only by the feeding of about 20 species of aphids. One species in particular, *Rhopalosiphum padi*, is responsible for most of the infections of the most common strain of the virus (the PAV strain) found in Illinois. Aphids become infective with the virus after feeding for many hours on an infected plant. Once the virus is acquired, the aphid vector is potentially infective for life.

Understanding the dynamics of virus spread within a field is key to constructing effective control strategies. To better understand these dynamics, a multiyear, multidisciplinary project, funded through the U.S. Department of Agriculture, has been conducted by Michael E. Irwin, Catherine E. Eastman, and Gail E. Kampmeier of the Survey’s Center for Economic Entomology, along with Adrianna D. Hewings of the USDA’s Agricultural Research Service. The research team hypothesized that the dynamics of barley yellow dwarf spread is different in fall-planted crops, such as winter wheat, than in those planted in spring, such as spring oats. The investigators set out to test whether fall infections have a greater impact on within-field spread than spring infections.

In both the fall and spring, infective and noninfective aphids fly into a newly planted field, feed, and perhaps deposit live young, which may then develop on a plant that was previously infected with the virus by a transient winged aphid. The developing aphids may thus acquire the virus from the host plant and...
Aphids may subsequently spread the virus by feeding on neighboring plants. The difference between the fall and spring is the early presence in the fall-planted crop of a pool of potentially infective and colonizing aphids that have left senescing crops and grasses. Early infections transmitted by these aphids will have the greatest impact on the severity of the disease.

The research team found that fall infections were spread by colonizing aphids to neighboring plants but that symptoms only showed up with the flush of new growth in the spring. There is little evidence that winged aphids acquire the virus from this source in the spring and transmit it to other plants within the field. Infective winged aphids arriving in the spring may transmit the virus to new plants, but the impact is minimal in the maturing crop.

Aphids are generally not able to overwinter on the crops in central Illinois. During three years of experiments, oats were planted near the end of March, and the first few winged aphids were trapped during the first or second week of April, when the plants were barely out of the ground. Aphid flights peaked between early May and early June. During the spring, between 5 and 20% of the aphids trapped flying over the experimental fields were infective with the PAV strain of the virus. Epidemics in spring oats depend on the early arrival of infective aphids and subsequent colonization of infected plants by nonwinged aphids that will spread the virus to neighboring plants. When aphid flights peaked in June, the oat plants were already too mature for the virus to have much of an impact on yield. However, large flights of aphids in early May in two of the three years caused these years to be considered epidemic for barley yellow dwarf.

Epidemiological information is essential to develop truly effective control strategies for barley yellow dwarf. One essential ingredient is a knowledge of the type of vector movement during epidemics; without this information, management tactics cannot be targeted on the weakest links of the epidemiological cycle. This information must be understood in the context of the influences it has on epidemics under different management systems. The key to good control is to integrate the various tactics into a cohesive strategy that ultimately reduces the impact of the virus on crop yield—not only over the short term but also over successive seasons—while safeguarding the environment and wildlife.

Michael E. Irwin and Gail E. Kampmeier, Center for Economic Entomology