The history of the ILLINOIS RIVER and the decline of a NATIVE SPECIES

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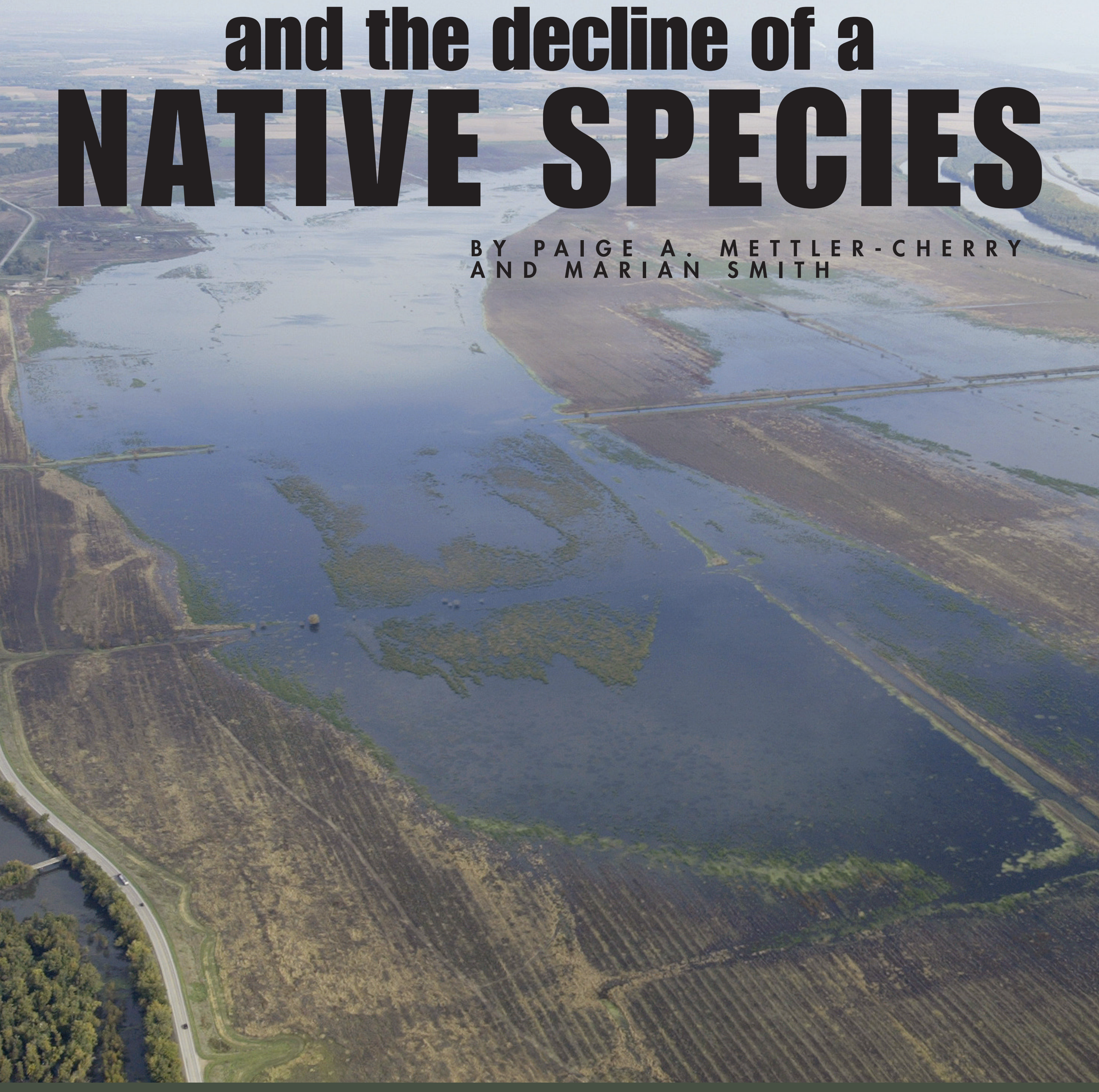


A very important advantage, and one which some, perhaps, will find it hard to credit, is that we could easily go to Florida in boats, and by a very good navigation. There would be but one canal to make . . .

Louis Joliet, 1674, making the earliest known proposal to alter the Illinois River (Hurlbut 1881)

Emiquon National Wildlife Refuge as it appears today. The corn and soybean fields (see page 38) have been replaced by the reappearance of Thompson and Flag lakes. The refuge already teems with wildlife, including many species of migrating waterfowl, wading birds, deer, and re-introduced native fish species. (Photo: Courtesy of the author)

Large river ecosystems are perhaps the most modified systems in the world, with nearly all of the world's 79 large river ecosystems altered by human activities (Sparks 1995). In North America, the Illinois River floodplain has been extensively modified and the flood pulse, or annual flood regime, of the river is distorted as a result of human activity (Sparks, Nelson, and Yin 1998). Although many view flooding as an unwanted destructive force of nature (mostly because of our insistence on living and working in floodplains that flood), the movement of water onto the floodplains (a flood pulse) is a natural process that restores and creates habitat for a tremendous diversity of species. It also provides other services such as sediment retention, groundwater recharge, nutrient storage and, paradoxically, flood abatement and storage. The study of flood pulses and their role in river-floodplain functioning was a concept first developed by scientists studying Amazonian floodplains and their role in river ecosystems (Junk 1982). These concepts have been applied to other large river ecosystems, including the Illinois River, giving us a much better understanding of the importance of keeping floodplains connected to their rivers.

The Illinois River and its basin form a unique ecological environment that was modified by substantial anthropogenic changes after non-indigenous settlement of Illinois. The dynamic nature of this system provided habitat for a wide diversity of floodplain species, including what was one of the largest commercial fisheries in the United States (Sparks *et al.* 2000). Although a large portion of the Illinois River floodplain habitat has been destroyed or severely modified, fifty percent of its floodplain functions as part of the river and provides a unique opportunity to study flood pulsing and the ecology of native species (Sparks 1995). We will discuss the recent history of the Illinois River and its basin, significant changes to the river system, and the effects of those changes on the threatened native plant species, *Boltonia decurrens*. Extensive research on this species serves to provide insight into the ecological functioning of the altered Illinois River system and provides a lesson on the consequences of habitat alteration and destruction.

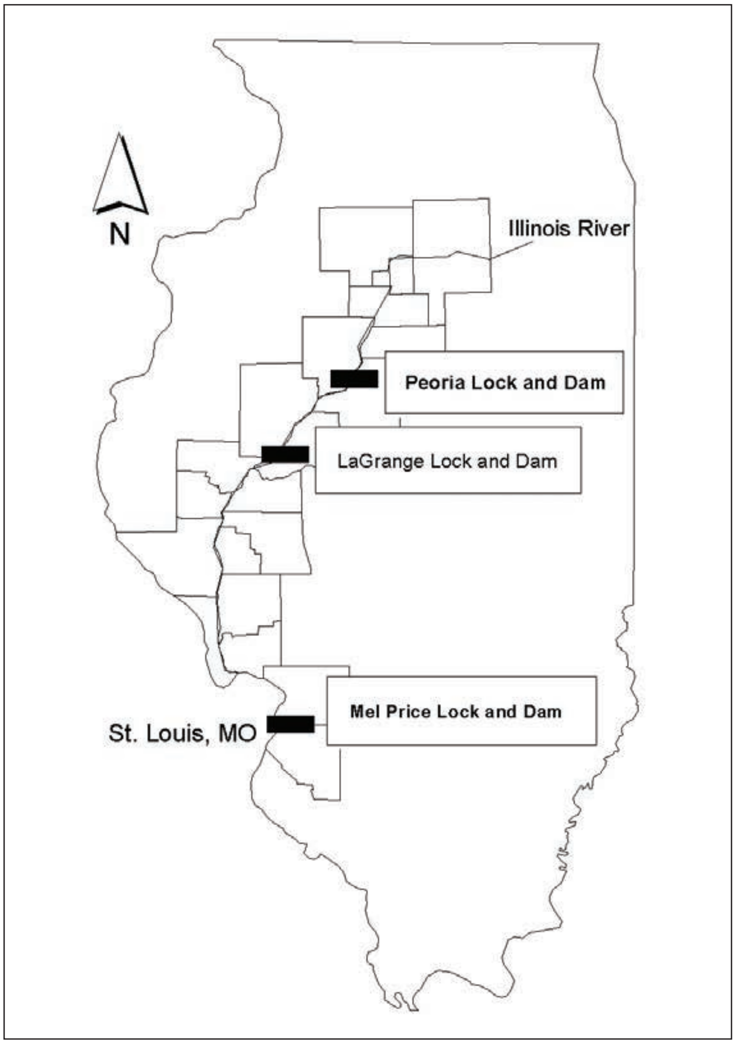
Description of the Illinois River and its Valley

To understand the importance of the Illinois River and its flood pulse to the floodplain communities, it is necessary to examine how geography and geology influence the hydrologic regime of this unique system. The Illinois River reaches from the confluence of the Kankakee and Des Plaines rivers, 45 miles southwest of Chicago, to just north of St. Louis, at the confluence of the Mississippi and Missouri rivers, spanning a total of 272.4 miles (Arnold *et al.* 1999; Barrows 1910; Warner 1998). Geologic formation and geographic structure of the river are sharply divided between the upper Illinois River and the lower Illinois River. The division occurs in the area known as "The Great Bend," approximately 63 miles below the head of the river. At this point in the river, the direction of flow changes from west to south as the river turns in a near ninety-degree angle at Hennepin, Illinois (Warner 1998; Arnold *et al.* 1999).

The upper Illinois Valley was formed during five major glacial periods, with the most recent glaciation occurring during the Wisconsinan glaciation 17,000-12,000 years ago (Arnold *et al.* 1999). The Wisconsinan glaciation occurred in three stages with the maximum extension of the ice occurring in the area of the Bloomington moraine south to Peoria. The subsequent advances and retreats of the glacier did not extend as far; however, they were the source for the abundant glacial water that carved the upper Illinois Valley as it drained from the proglacial Erie, Michigan, and Chicago lakes (Hajic 1990). Drainage from Lake Chicago (now the site of the city) was eventually diverted by glacial movement to present-day Lake Michigan and ceased draining into the Illinois River.

The lower Illinois Valley is much older than the upper and has been glaciated several times. The Illinoisan ice sheet covered much of Illinois, stopping 19.9 miles north of the Ohio River. The effects of the glacier are easily seen when comparing the flat agricultural fields of central and northern Illinois, which the glacier covered, to the Shawnee Hills of southern Illinois, where the glacier did not reach. The valley of the lower Illinois River is much broader and drained a greater volume of water during glaciation periods than it does at present. The pre-glacial channel that is now the lower Illinois River served as a drainage outlet for a much larger area than it does now (Horberg and Anderson 1950); prior to the Pleistocene glaciation, the ancient Mississippi River flowed through the lower Illinois Valley until the river was diverted to its present valley (Barrows 1910; Alvord and Burdick 1919; Mulvihill and Cornish 1929; Arnold *et al.* 1999; Warner 1998). To give a clear physical comparison, the width of the river valley above the Great Bend ranges from one to 1.5 miles, while below the Great Bend it ranges from two to five miles. The valley of the upper Illinois River is delineated by steep, rocky bluffs, while the valley of the lower Illinois River is bordered on the eastern bank by large, gravel terraces that resulted from deposition from glacial runoff (Sauer 1916).

Map of Illinois showing the historical distribution of *Boltonia decurrens* (counties outlined); and locks and dams on the Illinois and Mississippi rivers that control water levels at all *Boltonia decurrens* sites (black rectangles).
(Source: Smith, Caswell and Mettler-Cherry 2005)



> ***In its unimproved condition the flow of the Illinois River was so irregular that in former years, it became a reeking slough in seasons of drought, and in flood-time discharged occasionally a volume of water forty times that of its normal flow (Sauer 1916).***

As with the geology, there is a sharp differentiation between the gradient of the upper and lower Illinois River. Overall, the gradient of the Illinois River is very shallow, averaging 0.84 feet per mile (Hajic 1990). From the head of the river to Hennepin, the river falls 49.9 feet and from Hennepin southward to the mouth of the river at Grafton, the river falls only an additional 25.2 feet, for a total gradient of 75.4 feet from the head of the river to Grafton, where it converges with the Mississippi and Missouri rivers (Hajic 1990). This exceptionally low gradient will often result in the Mississippi River (with its larger volume and higher flow rate) acting as a dam on the Illinois, forcing water to actually flow upstream during periods of high water on the Mississippi (Sparks, Nelson, and Yin 1998). The shallow gradient, combined with a deep, wide valley, created a slow moving, aggrading river that, prior to human alteration, created and filled backwater lakes and sloughs repeatedly (Alvord and Burdick 1919). Typically, the Illinois had the highest flow rates during its regular flood season in the late winter and spring months, with low flow rates through summer, fall, and early winter. The average flow rate from 1890-1900 was 779.1 $ft^3 s^{-1}$, as compared to the modern Mississippi River which has an average flow rate of 572,000 $ft^3 s^{-1}$ (Alvord and Burdick 1919; N.P.S. 2009). President Thomas Jefferson had described the Illinois as "a fine river, clear, gentle, and without rapids; insomuch that it is navigable for batteaux to its source" (Jefferson 1787).

Human presence within the Illinois River Valley

> ***The Illinois Indians were handsome creatures (Gray 1940).***

Most discussions of indigenous people in Illinois begin with the Illiniwek, of which there were five tribes: the Peoria, the Kaskaskia, the Cahokia, the Michigamea, and the Tamaroa. By 1818 the Cahokia, Michigamea and Tamaroa had disappeared as distinct tribes, the remnants of the Kaskaskia lived on a 350-acre reservation near Kaskaskia, and the remnants of the Peoria lived in the upper Illinois River Valley (Buck 1967). As other American Indian nations were driven westward by non-indigenous settlers, the Illiniwek (later named "Illinois" by French traders who had difficulty pronouncing "Illiniwek") were displaced from their homelands by other Indians in the north, and white settlers from the south. After many years of conflict, the Iroquois broke the hold of the Illiniwek on the upper Illinois River Valley and the surrounding prairies. Much later, the retreating Iroquois drove out the Sauk and Fox, the Winnebago, the Kickapoo, and the Potawotami from their ancestral homes in Michigan and Wisconsin. Remnants of these tribes emigrated temporarily to northern Illinois lands, left by the annihilated Illinois tribes, until the few people left were driven westward again by non-indigenous soldiers and settlers. Eventually, they were forced onto reservations by the United States government (Bauxar 1959; Buck 1967; Kehoe 1981).

> ***A great part of the territory is miserably poor, especially that near Lake Michigan and Erie, and that upon the Mississippi and Illinois consists of extensive plains which have not had from appearances, and will not have, a single bush upon them for ages. The districts therefore within which these fall will perhaps never contain a sufficient number of inhabitants to entitle them to membership in the Confederacy (James Monroe to Thomas Jefferson, 1786).***

Wilhelm Lamprecht, "Father Marquette and the Indians." Louis Jolliet and Fr. Jacques Marquette in 1674 were the first Europeans to describe the Illinois River.
(Photo: Haggerty Museum of Art. Marquette University)

Human impact on the ecology of the river began after "discovery" of the river by the French clergyman Jacques Marquette and the French Canadian explorer Louis Joliet (Buck 1967). It was Joliet who made the earliest known proposal to modify the Illinois River by building a canal to connect the river to the Great Lakes (Hurlbut 1881). The French were the first non-indigenous settlers to traverse and live in the Illinois River Valley, and by 1679, Robert Cavalier (Sieur de La Salle) was establishing the first French colony, Fort Creve Coeur, at Lake Peoria. As did the American Indians before him, La Salle recognized the strategic advantage of the Starved Rock area with its high, rocky bluffs, and established Fort St. Louis des Illinois. After La Salle's death in 1687, the fort was left unprotected and was eventually abandoned (Sauer 1916). French fur trappers thrived on the abundant game found throughout the valley at this time, making it one of the most important fur-bearing areas of what was then the northwest territory of the colonies, with thousands of deer, bear, raccoon, muskrat, otter, and beaver pelts shipped out of this region (Buck 1967).

Despite early dismissal of the Illinois River basin as either a treeless desert (the prairies) or an inhospitable swamp (the wetlands), non-indigenous settlers began to populate the area. Illinois became a state in 1818 with a population of some 40,000, but the majority of these people lived in the southern region of the state, particularly in the area across the Mississippi River from St. Louis, and along the Ohio River (Starrett 1971). The Illinois River Valley had fewer than 2 people per square mile when statehood was granted by the federal government. In 1828, steam navigation was established on the river, making the valley easily accessible for additional human immigration. In 1840, the population of the Illinois River Basin was 109,000 (excluding Chicago), and by 1990 there were 8.5 million (Starrett 1971; Arnold *et al.* 1999). The sharp population growth after 1840 was the impetus for major changes in the physical characteristics of the river and the valley surrounding it.

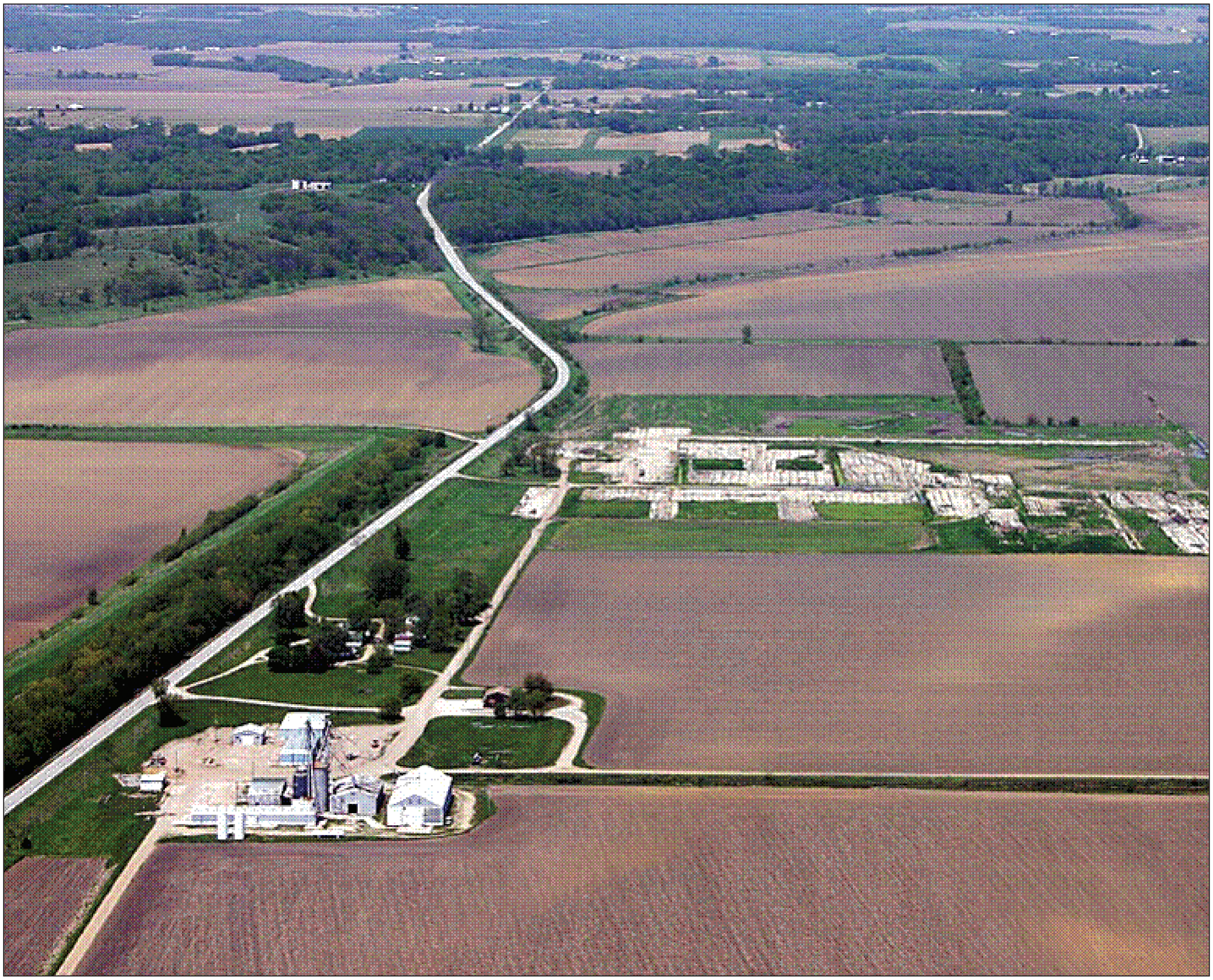
Major changes to the Illinois River and its floodplain

> *It may be expected confidently that its [the floodplain's] reclamation will take place within a brief period and will add an important class of lands to those already farmed. (Sauer 1916)*
>
> *It is a question of the first magnitude whether the destiny of the great rivers is to be the sewers of the cities along their banks or to be protected against everything which threatens their purity. (Justice Oliver Wendell Holmes, 1906, Missouri v. Illinois 1906)*

As the human population in the Illinois River Valley increased, political pressure also increased to open the water corridor first proposed by Joliet, thereby connecting the Great Lakes to the Gulf of Mexico, via the Mississippi. The Illinois and Michigan Canal was opened in 1848, but closed in 1907 due to competition from the railroads (Conzen and Morales 1989). The canal had a minor effect on the hydrology of the Illinois River, but the connection of the river to the Great Lakes had a far-reaching biological impact by creating the first corridor for exotic species invasion (Stoeckel *et al.* 1996).

After the Illinois and Michigan Canal was closed, pressure mounted to construct a much larger canal. Explosive growth of Chicago forced local officials to deal with a massive and deadly sewage problem. Raw sewage and garbage dumped into the Chicago River flowed past the Two Mile Crib, the source of Chicago's drinking water in Lake Michigan. Pumping failed to clear the sluggish Chicago River, but pushed the sewage downstream enough to create conflicts with other communities, and several deadly outbreaks of smallpox, dysentery, and typhoid caused thousands of deaths and panic in the city. Demand for a permanent solution resulted in formation of the Sanitary District of Chicago in 1889, and ground was broken for the Chicago Sanitary and Ship Canal in 1892. During construction, the State of Missouri

Aerial view of Wilder Farms and Stockyards before the property was purchased for the Emiquon National Wildlife Refuge by the Nature Conservancy and the US Fish and Wildlife Service. (Photo: Courtesy of the author)



moved to prevent the opening of the canal by filing suit with the U.S. Supreme Court. Sewage buildup on the Chicago River was so bad that in summer months, the river would crust over enough that chickens and dogs walked across the river. Missouri argued that the flow of water would dislodge the accumulated sewage along the river and send it downstream with the rest of the effluent where it would affect the Mississippi River, a principal water supply of Missourians. Before the issue was decided in court, Chicago Sanitary District Commissioners secretly destroyed the temporary dam separating the Chicago River from the Chicago Sanitary and Ship Canal in January 1900, to circumvent legal action that might prevent the opening of the canal (Miller 1996). The result was a complete reversal of the Chicago River and initiation of flow from Lake Michigan into the Illinois River, again connecting the Great Lakes to the Mississippi River (Moses and Kirkland 1895) and the Gulf of Mexico. The 28-mile canal runs parallel to the Illinois and Michigan Canal, with a depth of 35 feet. It is 160 feet wide at its narrowest and 306 feet wide at its widest and is larger than the Suez, Panama, and Erie canals (Miller 1996; Moses and Kirkland 1895).

The Chicago Sanitary and Ship Canal was successful in diluting raw sewage effluent generated by Chicago and diverting it downstream from the city's water supply, but not without the consequences feared by the State of Missouri. As a result of raw sewage moving downstream, a catastrophic pollution problem was created in the upper Illinois River, producing a dead zone with no aquatic life south to Chillicothe, approximately 142 miles southwest of Chicago (Mills, Starrett, and Bellrose 1966; Bellrose, Paveglio, and Steffeck 1979). By 1910, the zone was extending farther down river and was destroying the plant food sources necessary to support wildlife populations (Sparks 1984; Sparks *et al.* 2000). In 1922, the Metropolitan Sanitary District of Greater Chicago began operating the first sewage treatment plant, resulting in gradual improvement of water quality in the Illinois River.

The effects of the Chicago Sanitary and Ship Canal on the Illinois River and its ecology are profound. Present-day flow of the Illinois River is 62 percent higher since modification of the river began (Alvord and Burdick 1919; Arnold *et al.* 1999). The increased depth of the river attributable to the canal is 2.8 feet, which had the subsequent effect of increasing the area and depth of the bottomland lakes, also flooding bottomland forests. Prior to the opening of the canal, there were approximately 54,000 acres of bottomland lakes and marshes, and after the diversion, this increased to over 120,000 acres, or thirty percent of the estimated 400,000-acre floodplain (Forbes and Richardson 1919; Bellrose, Paveglio, and Steffeck 1979). This was soon to be reduced by the formation of levee and drainage districts throughout the Illinois River Valley.

> ***The history of wetlands drainage in the Illinois River Valley shows that privatization of a resource does not necessarily lead to conservation (Schneider 1996).***

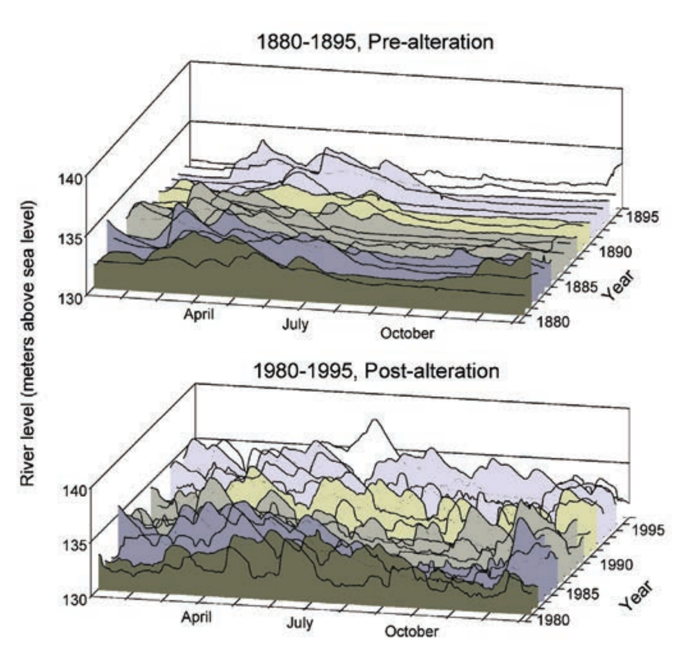
The backwater lakes and wetlands of the Illinois River Valley are a result of the unique properties of the Illinois River. The aggrading river formed low, natural levees along the shoreline that impounded floodwater into the backwater lakes seen throughout the valley (Alvord and Burdick 1919; Mulvihill and Cornish 1929). These shallow lakes take in water during periods of high flow and then draw down to low levels in the summer months, exposing large areas of mudflats that allowed the establishment of lush wetland vegetation critical as a food source for migrating waterfowl. The cyclical inflow of flood waters, deposition of sediment over the backwater areas, and lush growth and decay of vegetation, built an extremely rich, thick soil base that was later to be exploited for agricultural purposes (Alvord and Burdick 1919; Bellrose, Paveglio, and Steffeck 1979).

This highly productive and diverse environment made the area attractive to private and commercial hunters and fishermen. Up until the late 1800s, the backwater lakes and wetlands were considered a "commons" or area open to public use. As the population of the Illinois River Valley grew, use of these areas became more extensive. The attractiveness of these areas also came to the attention of affluent sportsmen from Chicago, Indianapolis, and Peoria, who increasingly purchased large tracts of floodplain to form private duck hunting clubs. The Swamp Land Act, passed in 1850, was the beginning of several legislative acts that accelerated the loss of the floodplain as public domain by giving the state title to the property in an effort to convert wetland areas to farmland. The state passed these titles on to the individual counties who sold the land. Privatization of the floodplain brought the landowners into direct conflict with local fishermen, hunters, and farmers who had used these areas for decades for subsistence (Schneider 1996). This conflict occasionally escalated into violence, with private wardens of the duck clubs confronting poachers who felt they had a legal right to be on the water. This belief was based on an Illinois law governing access to wetlands that essentially exempted trespassers when access was gained to an area via water connected to waters of the state (Schneider 1996). In other words, if you could get there by boat, you were legal. As litigation and security expenses increased, many of the clubs opted to convert their wetlands to more profitable agricultural land, ushering in rapid growth of levee and drainage districts throughout the Illinois River Valley. The first levee district was organized near Pekin in 1889 and by the late 1920s, some 204,916 acres of floodplain were behind levees. There are currently 54 levee districts in the Illinois River Valley (Bellrose, Paveglio, and Steffeck 1979; Thompson 1989).

The effects of channelization from levees are far-reaching throughout the valley. The wetlands were destroyed and converted to agricultural use, and by draining the water and destroying the vegetation, habitat for wildlife was destroyed (Bellrose 1945; Bellrose, Paveglio, and Steffeck 1979; Mills, Starrett, and Bellrose

Daily water-level hydrographs (meters above mean sea level) from 1880 to 1895 and from 1980 to 1995 measured at a USACE gage station located in the La Grange navigation pool

(Source: Smith, Caswell and Mettler-Cherry 2005)



1966). By eliminating access to the floodplain, water is confined to the main channel of the river, thereby increasing the height and velocity of the water (much the same as putting your thumb over the end of a garden hose) and increasing the period of inundation during floods when otherwise the wetlands would have held the water like a sponge until it could move through the soil to the groundwater (Mulvihill and Cornish 1929; Sparks 1995). Pollutants are concentrated in the main channel and sediment is flushed to the channel and carried downstream instead of being deposited on the floodplain (Sparks, Nelson, and Yin 1998).

Late year low flows combined with a shallow channel made it difficult to maintain consistent, navigable conditions for barge traffic on the Illinois River. In order to create these conditions, construction began on the Illinois Waterway in 1919 to create and maintain a larger, deeper channel nine feet deep and at least 300 feet wide from Lake Michigan to the Mississippi River. In 1930, the Nine-Foot Navigation Channel Project and the River and Harbor Act authorized the United States Army Corps of Engineers (U.S.A.C.E.) to finish the 75 percent completed State of Illinois project, and subsequently assigned responsibility for maintenance of the navigation channel to the U.S.A.C.E. A series of seven locks and dams was constructed in the 1930s ranging from ten to forty feet in height (Waller 1972). After the system was completed in 1939, the Illinois River became a series of navigation pools with each pool named for the dam immediately downstream (U.S.A.C.E. 1996).

The lock and dam system creates a wide range of conditions within the environment of the navigation pool itself. The upstream end of the pool is usually somewhat similar to what may be considered natural conditions, while the downstream end of the pool (just above the dam) is deeper and wider, causing permanent inundation of floodplain areas adjacent to the pool. By eliminating water recession in these areas, any chance for wetland vegetation to establish is eliminated (Mills, Starrett, and Bellrose 1966; Sparks, Nelson, and Yin 1998). Overall, navigation dams prevent the river from receding to the low water levels once a natural part of the regime. They hold water during low flow but, during large floods, the water retaining structures are lowered to the river bed and do not control floods. Although public attention focuses on major floods, the smaller spikes in water level caused by navigation dam operation have proven to have detrimental effects on the flora and fauna of the Illinois River system. Late season spikes in water levels, which have become more common, result in the loss of wetland vegetation that cannot adapt to ill-timed floods (Bayley 1991; Bellrose, Paveglio, and Steffeck 1979).

Agriculture was identified by the Illinois Environmental Protection Agency as the source of pollution for 99 percent of the impaired rivers, streams, and lakes (C.T.A.P. 1994).

Agriculture is the dominant land use in the State of Illinois, with 76.6 percent of Illinois land area in production and 82 percent of the Illinois River drainage basin used for agriculture (Arnold *et al.* 1999; Warner 1998). Within the Illinois River watershed, the types of crops produced have changed dramatically. Until 1925, row crops and cover crops shared equal acreage, but by 1987, row crops covered ninety percent of the agricultural area in the Illinois River watershed. Production of grassy cover crops such as wheat, oats, and hay has been replaced with row cropped soybeans and corn (Demissie, Keefer, and Xia 1992). The Critical Trends Assessment Program (C.T.A.P.) and the Illinois Environmental Protection Agency have identified row crop agriculture as the primary contributor to sediment load in the Illinois River and its backwater lakes, resulting in a muddy river replacing the "clear, gentle" river of Jefferson. Data collected by the U.S. Geological Survey show that on average, 13.8 million tons of sediment is delivered to the Illinois River Valley. The average outflow of sediment is 5.6 million tons, leaving 8.2 million tons deposited in the Illinois River Valley annually (Demissie and Akanbi 2000). The loss of buffering floodplain wetlands exacerbates this problem. Without wetlands, water runs off directly from the fields into the waterways instead of percolating down to the groundwater. The water carries the fine textured particles typical of Illinois soils with it, and the result is a much more rapid increase in water levels in the Illinois River with water that is muddy from the high sediment load. The sluggishness of the Illinois, as compared to the high flow rates of its tributaries, then contributes to sedimentation of the backwater lakes. By 1990, the backwater lakes had an average capacity loss of 72 percent (Demissie, Keefer, and Xia 1992). Sedimentation has also changed the bottom profile of the lakes to a shallow, bowl shape devoid of the habitat heterogeneity that helps to promote species diversity (Bellrose, Paveglio, and Steffeck 1979).

The overall effect of these combined changes has left the river unrecognizable as the lush, wildlife-rich system that greeted the first European explorers. The foundation of a river-floodplain system is the flood regime, and when that foundation is altered as it has been for the Illinois River, the effects on native species are profound. Until the early 1900s, the Illinois River was characterized by moderate, late winter-early spring flood pulses, followed by recession of water during the summer. Early year flooding provided nursery habitat for spawning fishes while low water levels during the summer months allowed for the establishment of emergent

wetland vegetation that was critical for feeding vast flocks of waterfowl as they migrated to their winter habitat. Today, the river has a chaotic, hydrologic regime with floods occurring at all times during the year, but most destructively during the late summer months, which is the critical growing season for floodplain plants that form the basis of the entire food web (Sparks 1995; Smith and Mettler 2002; Mettler-Cherry, Smith, and Keevin 2006). An understanding of the relationship between the organisms of the Illinois River Valley and the historical flood pulse regime helps to explain the endangered status of many Illinois River native species that have evolved to require the predictable, moderate flood events natural to the river system (Bellrose *et al.* 1983; Sparks 1995).

Boltonia decurrens, a fugitive species native to the Illinois River Valley

> ***Fugitive species are forever on the move, always becoming extinct in one locality as they succumb to competition and always surviving by reestablishing themselves in some other locality as a new niche opens (G. E. Hutchinson 1951).***

Fugitive species depend on frequent fluctuations in habitat to provide refuges in which to establish new populations (Harper 1977; Hutchinson 1951). The natural water-level fluctuations in large river-floodplain ecosystems create and maintain an early successional environment (Junk, Bayley, and Sparks 1989) ideal for the establishment and persistence of fugitive species. The historical cycle of annual, regular flooding of the Illinois River provided the mechanism that created this habitat (Sparks 1995). Established vegetation was removed by the inundation of floodwater, and subsequent recession from the floodplain wetlands renewed native herbaceous wetland vegetation. Modification of the flood characteristics of the Illinois River has reduced habitat availability for fugitive species (Smith, Caswell, and Mettler-Cherry 2005), which are particularly sensitive to habitat alteration and loss (Hutchinson 1951).

Boltonia decurrens provides a grim example of the consequences of disruption of the natural flood regime for species adapted to dynamic river habitats. It is a fugitive species that occurs only on the floodplains of the Illinois River and in the area of its confluence with the Mississippi River (Schwegman and Nyboer 1985; Smith and Keevin 1998). In spite of prolific seed production and the ability to reproduce vegetatively (Smith, Caswell, and Mettler-Cherry 2005), the number of naturally occurring populations, which fluctuates annually, has declined over the past 100 years (Schwegman and Nyboer 1985; Smith 1995, 2002). In 1988, the U. S. Fish and Wildlife Service (U.S.F.W.S.) placed *Boltonia* on the federal list of threatened species (U.S.F.W.S. 1988). It is currently listed as a “species of concern” in Missouri (M.D.C. 1999) and threatened in Illinois (Herkert and Ebinger 2002).

Boltonia requires an appropriately timed natural or human disturbance to create and maintain habitat (Schwegman and Nyboer 1985; U.S.F.W.S. 1990). Its historical habitat was in wet prairies, in shallow marshes and along the open shores of creeks and backwater lakes of the Illinois River (Schwegman and Nyboer 1985). Labels from nineteenth-century herbarium collections indicate that it grew in contiguous populations throughout the Illinois River Valley (U.S.F.W.S. 1990). Collections since 1970 are limited to human-disturbed ground near the Illinois River (Morgan 1980) and open, muddy edges of floodplain forests (Kurz 1981; U.S.F.W.S. 1990). Populations now occur in three disjunct clusters (See map on page 36) that are associated with the pools created by navigation dams—Peoria and La Grange on the Illinois River and Melvin Price (Lock and Dam 26) on the Mississippi River (Mettler-Cherry and Smith 2006). It is the general consensus of conservation personnel that the threatened status of *Boltonia* is due to a reduction in suitable habitat (Schwegman and Nyboer 1985; U.S.F.W.S. 1990; Smith, Caswell, and Mettler-Cherry 2005).

Flooding provides a regime that creates the high light environment required by *Boltonia* for germination (Baskin and Baskin 1988; Smith and Keevin 1998) and growth (Smith 1993). Seeds germinate readily on the surface of either water or moist soil if they are exposed to light; however, when covered by as little as 0.04 inches of silt, germination does not occur (Smith and Keevin 1998). The increased sediment load of the Illinois River (Lee and Bhowmik 1979) has reduced water clarity, and its deposition on the floodplain rendered areas once ideal for the establishment of *Boltonia* unsuitable for seed germination and population establishment. This was dramatically illustrated late in the summer of 1994, when heavy layers of silt, deposited by the 1993 flood, cracked and exposed the pre-flood soil surface. Seeds of *Boltonia* were exposed and germinated, with rosettes emerging from the crevices in August. Large areas between the cracks were devoid of seedlings, but by September, a small population of *Boltonia* rosettes had begun to mature and flower. Unfortunately, germination occurred so late in the season that few individuals flowered and produced seeds (Smith, Caswell, and Mettler-Cherry 2005).

The inflorescence of *Boltonia decurrens*. Each “flower” is actually several hundred individual flowers packed together in a receptacle. (Photo: Courtesy of the author)

Under ideal growth conditions (open areas with moist soil), *Boltonia* can reach a height of eight feet and produce up to 30,000 seeds per individual; however, if light is limited or seed germination is delayed by flooding during the critical growing season (June through October), plants often flower and die when less than eighteen inches tall (Smith and Keevin 1998). Seed production in these late-establishing plants is reduced to fewer than 100 seeds per individual (Smith and Keevin 1998). As seedling establishment and survival is extremely low (less than ~0.01percent) under good field conditions (Moss 1997), small plants have little probability of producing enough seedlings to create a new population in the spring. Newly emerged *Boltonia* seedlings are less than 0.25 inches across the span of the first leaves, and cannot compete for light with larger seedlings or established vegetation. They do not survive unless they become established on bare soil left by receding floodwaters (Smith and Mettler 2002).

Boltonia also reproduces vegetatively: rosettes are formed at the base of the senescing mature plant, and become nutritionally independent by the time the mother plant dies (Baker 1997). All plants that flower die at the end of the flowering season, and no persistent root stock is present from which plants may emerge the following spring; therefore, each new population must be established by new seedlings or vegetative rosettes that were produced the previous autumn. If the site is inundated by floodwaters too early in the fall, or if the population experiences a severe late summer drought, vegetative rosettes are not produced. Thus, vegetative reproduction, as well as seed production and seedling establishment, are dependent upon an appropriately timed flood and sufficient precipitation (Smith, Caswell, and Mettler-Cherry 2005).

The role of flooding in seed dispersal, germination and seedling recruitment has been firmly established for *Boltonia* (Smith and Keevin 1998). As floodwaters recede, seeds are deposited on the shores and seedlings become established in the bare mudflats. In 1994, after the Midwest flood of 1993 had cleared existing vegetation from vast areas of the Illinois floodplain, populations of *Boltonia* that had been near extirpation exploded in size (Smith 1995; Smith *et al.* 1998). At Gilbert Lake in Jersey County (1.6 miles from the river's confluence with the Mississippi River), a population that had consisted of fifty flowering plants in 1992 increased to more than 20,000 individuals in1994 (Smith *et al.* 1998). Because of the alteration of the hydrology of the Illinois River, the floodplain area exposed during periods of low flow has been reduced (Bellrose, Paveglio, and Steffeck 1979). Although germination of *Boltonia* readily occurs while seeds are floating on floodwaters, eventually the water must recede for seedlings to become established (Smith and Keevin 1998). The levees and navigation dams on the altered Illinois River serve to isolate seeds from suitable habitats and prevent the free flow of seeds along the river where they might have found a suitable niche.

Historically, annual flooding created the open habitat required for optimal growth of *Boltonia* by eliminating less flood-tolerant species and clearing away the litter cover produced by dead vegetation. Field observations and laboratory studies have shown that *Boltonia* has several adaptations to flooding that provide a significant advantage over potentially competitive, but less flood-tolerant, species. In areas where floodwaters have recently receded, *Boltonia* is often the only surviving species. In a laboratory study that compared tolerance to root-zone flooding in *Boltonia* and *Conyza canadensis* (an annual species that often invades *Boltonia* population sites), Stoecker, Smith, and Melton (1995) reported that after 28 days of flooding, survival was significantly greater in *Boltonia* as compared with *C. canadensis*. Roots and stems of *Boltonia* exposed to flooded conditions produced more oxygen-conducting tissue, which enhanced the flow of air from the above-water stems and leaves to the roots, preventing them from rotting. In subsequent studies, Stoecker (1996) demonstrated that *Boltonia* is capable of maintaining low rates of growth while completely submersed. Under conditions of reduced light, as would occur in sediment-heavy floodwaters, plants died (Stoecker 1996); therefore, the clarity of floodwaters is of critical importance to the survival of submersed individuals of *Boltonia*.

Clustered in a tight ring, vegetative rosettes are produced at the base of the senescing mother stem in the late fall. These rosettes will overwinter and then bolt and flower the following year as mature plants. (Photo: Courtesy of the author)

The alteration of the historical flood regime has destroyed habitat and isolated populations of *Boltonia* from the normal ebb and flow of the river floodwaters, resulting in its restriction to human-disturbed habitats (U.S.F.W.S. 1990; Smith and Keevin 1998). Because of *Boltonia*'s fugitive nature, it cannot be protected by standard conservation practices of isolating and protecting selected populations, or restored to its historical abundance without a comprehensive change in river management policies.

Restoration of the flood pulse to the Illinois River Valley

Various terms have been used to describe improvements made to river environments, all of them suggesting some level of restoration of ecosystem function (Brookes and Shields 1996). True restoration, as proposed by Cairns (1991), requires the re-creation of the structure and function of an ecosystem to pristine conditions. Little historical data are available for the majority of the world's large, temperate river-floodplain systems making true restoration an impossibility (Gore and Shields 1995); however, sufficient historical hydrological and ecological data are available concerning the Illinois River system to form a reasonable comparison with the pre-disturbance regime (Bellrose *et al.* 1983; Sparks 1995). Because of social and economic restraints, however, the complete reversal of human disturbance is not likely (Sparks *et al.* 2000). To be politically and economically feasible, any systemwide changes in the Illinois River must find a balance between navigation interests, farmers, recreational users and the rehabilitation and protection of the natural biota (Theiling 1995; Sparks *et al.* 2000).

If private owners are unwilling to accept limits on unsafe building practices in known hazardous areas, why should the nation hold them harmless from the results of their own free choice? (Platt 1994).

The United States has never viewed flooding from a systemwide perspective. Government agencies and individual communities have spent vast sums of money on a fragmented system of structural flood control measures (Wright 1996). The design of the district levee system in Illinois, whereby each district is given the authority to impose taxes to build and repair flood control structures, results in a patchwork of levees, with each district giving priority to its own immediate problems (Mulvihill and Cornish 1929; Thompson 1989). Downstream effects are seldom considered, as there is little incentive for the coordination of flood control efforts (Galloway 1995). What may prevent a flood in one district may ensure flooding downstream, thereby exacerbating flood losses on a large segment of the river (Larson 2009). This is a recurring pattern throughout flood-prone areas in the United States (Wright 1996). The government continues to offer financial incentives that encourage repetitive rebuilding in areas not suitable for construction and habitation (N.W.F. 1999; Larson 2009). The rebuilding of a larger and more "flood proof" levee in Chesterfield, following the devastating levee break and destruction of the 1993 flood, is an example of how the federal flood-protection policy operates. Is the Chesterfield area guaranteed 500 years of flood protection as suggested by proponents? The flood-protection rating of levees is based only on the *probability* of having a flood of that magnitude every 500 years, so each new flood season presents an unknown threat (Pilkey and Pilkey-Jarvis 2009; Larson 2009). Witness the 500-year flood of 1993, which, on portions of the Illinois River, was followed by another 500-year event in 1995. Every new or enhanced flood-prevention structure that is constructed increases the volume and velocity of flow and further exacerbates the extent and severity of flood damage. As long as the government continues to encourage habitation and development of natural floodplains, and uses taxpayer money to reimburse private losses, reconnection of the Illinois River to its floodplain will not be possible.

Although current practices are inconsistent with the restoration of a systemwide flood pulse, some conservation groups are planning and executing strategies for restoring the natural hydrology to some portions of the Illinois River. The Nature Conservancy (T.N.C.), in cooperation with the U.S.F.W.S., the Illinois Department of Natural Resources and a team of scientific advisors, has developed a strategic plan for the Illinois River (T.N.C. 2009). In 1997 and 2001, T.N.C. purchased property totaling 8,500 acres of former floodplain land on which they are reconnecting, through gates in the levee, the former floodplain to the river. As the hydrology of the reclaimed floodplain improves, plants and aquatic communities of the historical backwater lakes are being reintroduced. Because private ownership carries with it a significant measure of control over floodplain issues, these areas may serve as models to government agencies for the restoration of the flood pulse on public lands.

Although the former range and abundance of *Boltonia* is unlikely to be realized, its extinction may be averted by management regimes on these reclaimed floodplains. *Boltonia* is a target species for T.N.C. restoration, and studies of the dynamics of populations in the reclaimed areas will provide evidence of the benefit of a more natural flood regime to fugitive floodplain plants that may be applied to large floodplain-river systems throughout the country.

Mettler-Cherry on a research outing on the flooded Illinois River.
(Photo: Courtesy of the author)

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Mettler-Cherry on a research trip in the wetlands adjacent to the Illinois River.
(Photo: Courtesy of the author)