WISCONSIN'S DISAPPEARING OXBOW LAKES

David W. Marshall

Barneveld, Wisconsin

During the 30 years I worked for the Wisconsin Department of Natural Resources (WDNR), and well into my retirement, oxbow lakes were rarely the focus of monitoring and management. Oxbow lakes, also referred to as sloughs, are former river channels. It wasn't until late in my career when I learned the importance of these lakes. After I retired in 2006 and established Underwater Habitat Investigations LLC (UHI), I was finally able to learn more about these important waters.

From 2007–2012, I surveyed fish populations in oxbows along nine rivers in southern Wisconsin (Figure 1). I applied for and received numerous state grants sponsored by nonprofit organizations and county governments. UHI also benefited from the help of WDNR staff and other volunteer "slough pirates." The goal was to assess the distribution of rare off-channel river fishes including Weed Shiner *Notropis texanus*, Pugnose Minnow *Opsopoeodus emiliae*, Starhead Topminnow *Fundulus dispar*, Western Banded Killifish *Fundulus diaphanus menona*, Lake Chubsucker *Erimyzon sucetta*, Pirate Perch *Aphredoderus sayanus*, and Mud Darter *Etheostoma asprigene*. I also collected information on habitats and associated fish species. Fish sampling gear I used included a single-probe DC electrofisher powered by a Honda 1000 generator. A long-handled small-mesh dip net was great for topminnows. I rarely used seines because the backwaters were often too snaggy and weedy to be seined effectively. The other problem with seines is the lengthy time needed to sort fish from plant debris caught in the net, thus resulting in dead fish.

Figure 1: Map of rivers surveyed for rare/uncommon off-channel fish populations.

Photos by the author.

Dave Marshall is a retired Water Quality Biologist for the Wisconsin Department of Natural Resources and covered southwestern Wisconsin and the Lower Wisconsin River.

The surveys showed that oxbow lakes with greater species richness and numbers of rare fishes possessed strong connections to the rivers and were also spring fed (Figure 2). Pirate Perch, Starhead Topminnow, and Mud Darter were three of the study species regularly found in southwest Wisconsin rivers. Table 1 lists the top ten most common fish associated with these three species. The surveys also revealed:

- the first documented Western Banded Killifish in Wisconsin River backwaters.
- the first Starhead Topminnow and invasive Western Mosquitofish *Gambusia affinis* along the Lower Sugar River.
- the Lower Wisconsin River has the largest Starhead Topminnow population in Wisconsin.

Along with rare fish species, the backwater assemblage typically included Tadpole Madtom *Noturus gyrinus*, Central Mudminnow *Umbra limi*, Grass Pickerel *Esox americanus vermiculatus*, Green Sunfish *Lepomis cyanellus*, Warmouth *L. gulosus*, Bluegill *L. macrochirus*, and Largemouth Bass *Micropterus nigricans* (recently split from *M. salmoides*), as well as many other species.

Oxbows that receive groundwater generally have favorable water quality (Amoros and Bornette 2002). In less disturbed rivers, backwater habitats typically range from temporary flood pools to permanent lakes with strong connections to rivers. As a result, biodiversity in floodplains can be very high; they are among the most productive ecosystems on Earth (Opperman et al. 2010). Oxbow lakes support both off-channel and riverine fish populations

Figure 2. High-quality Black River oxbow.

Table 1. Top 10 off-channel fish species associated with Pirate Perch, Mud Darter, and Starhead Topminnow in southwest Wisconsin rivers.

Pirate Perch *Aphrododerus sayanus*	Mud darter *Etheostoma asprigene*	Starhead topminnow *Fundulus dispar*
Bluegill *Lepomis macrochirus*	Bluegill *Lepomis macrochirus*	Bluegill *Lepomis macrochirus*
Largemouth Bass *Micropterus nigricans*	Largemouth Bass *Micropterus nigricans*	Largemouth Bass *Micropterus nigricans*
Grass Pickerel *Esox a. vermiculatus*	Grass Pickerel *Esox a. vermiculatus*	Grass Pickerel *Esox a. vermiculatus*
Central Mudminnow *Umbra limi*	Central Mudminnow *Umbra limi*	Central Mudminnow *Umbra limi*
Mud Darter	Pirate Perch	Pirate Perch
Starhead Topminnow	Warmouth *Lepomis gulosus*	Mud Darter
Warmouth *Lepomis gulosus*	Starhead Topminnow	Warmouth *Lepomis gulosus*
Yellow Bullhead *Ameiurus natalis*	Green Sunfish *Lepomis cyanellus*	Yellow Bullhead *Ameiurus natalis*
Tadpole Madtom *Noturus gyrinus*	Yellow Bullhead *Ameiurus natalis*	Lake Chubsucker *Erimyzon sucetta*
Green Sunfish *Lepomis cyanellus*	Pumpkinseed *Lepomis gibbosus*	Green Sunfish *Lepomis cyanellus*

and include habitat for reproduction, early life history stages, lateral migrations, and refugia when river conditions become stressful (Bayley 1995; Killgore and Baker 1996; Roach et al. 2009; Miyazono et al. 2010; Slipke et al. 2005).

FLOODPLAIN AGGRADATION

In spite of their ecological importance, floodplains are among the most degraded ecosystems in the US and globally (Opperman et al. 2010). In many of the southwest Wisconsin watersheds I sampled, floodplain sediment deposition reduced connectivity between rivers and oxbow lakes. Under these conditions, rivers flow between steep banks of an elevated floodplain, what geologists describe as human accelerated floodplain aggradation (Knox 2006). Nearly 200 years of overbank sedimentation has reduced floodplain habitats in many agricultural watersheds. This means many fish species have lost access to spawning sites, and lateral fish migrations are becoming rare. In addition to loss of river connectivity, oxbows in sediment-deposited floodplains become perched above the groundwater table (Figure 3). Without groundwater inputs, oxbows often dry up during the summer months.

Figure 3. This oxbow was elevated above the water table in an aggraded floodplain. These types of oxbow lakes are most vulnerable to droughts and climate change.

GROUNDWATER POLLUTION

The Lower Wisconsin River flows west through the unglaciated Driftless Area and empties into the Mississippi River. Unlike the many other southern Wisconsin rivers that are disconnected from their floodplains, the Lower Wisconsin River remains well-connected to its natural floodplain. This connectedness is an important reason why the Lower Wisconsin State Riverway (LWSR) supports 98 fish species (Lyons 2005) and explains why the vast network of LWSR oxbow lakes has been described as a “fish safe haven” (Marshall and Lyons, 2008).. Special designations have been established to protect the river’s rich biodiversity including the 32,000 ha LWSR, Clean Water Act Exceptional Resource Water (ERW), and Ramsar Convention Wetland of International Importance.

Prior to the federal Clean Water Act implementation, from about the mid-twentieth century to the late 1970s, the Wisconsin River was severely polluted from the pulp and papermill industry (Ball and Marshall 1978). Oxbows along the LWSR likely functioned as refugia during the worst periods of industrial wa-

Figure 4. Clear Lake along the LWSR was an active channel and part of a braided river system. Clear Lake and most other Lower Wisconsin River oxbows are typically long and narrow. Sediment scouring can occur when the river reclaims the oxbows during floods. Most of the LWSR oxbows looked very similar to Clear Lake until nitrate pollution degraded them.

Figure 5. Jones Slough along the LWSR. This (spring lake) oxbow was pristine as recently as 2004 before nitrate contaminated groundwater degraded lake water quality.

Figure 6. Beavers can restore off-channel habitats in aggraded river floodplains. A beaver dam is located on the right side of the photograph. Jean Unmuth is seen dipnetting Starhead Topminnow in the beaver pond.

ter pollution. The massive aquifer beneath the river's Pleistocene sand terrace sustained the oxbows' water quality and diluted the industrial pollution. Some of the LWSR oxbows are classified as spring lakes since they are mostly groundwater fed and lack surface water inlets.

Until recently, the LWSR supported the most pristine oxbows in the state (Figure 4). By 2011, water quality had changed. Agriculture had become industrialized across the river sand terrace. Liquid manure and nitrogen fertilizers were applied in greater amounts needed for higher crop yields. The groundwater beneath the sand terrace quickly became polluted with very high nitrate concentrations. High nitrate levels can affect lakes and streams in two ways: eutrophication and toxicity. As the nitrate-contaminated groundwater reached the oxbow lakes, dense mats of duckweed and filamentous algae began to blanket the water surface of previously clear waters (Figure 5). Dense mats of free-floating plants are also plaguing many Mississippi River floodplain lakes (Giblin et al. 2013; Houser et al. 2013).

The same aquifer which sustained high quality LWSR oxbow lakes for millennia had become polluted with nitrate concentrations two or three times higher than the Drinking Water Enforcement Standard of 10 mg/l. In addition to human infant health concerns (methemoglobinemia or blue baby syndrome), many aquatic animals are also sensitive to high nitrate concentrations. A maximum of 2 mg/l NO_3-N is recommended to protect environmentally sensitive fish, amphibians, and invertebrates (Camargo et al. 2005).

Nitrate-laden water degraded numerous state-endangered Starhead Topminnow habitats along the Lower Wisconsin River, such as surface mats of free-floating plants. Our recent conservation aquaculture project, described in several *American Currents* issues, was a response to this threat. Other species threatened by nitrate pollution include Lake Chubsucker, which we began raising this year to expand their distribution upstream of the severe pollution.

WHAT CAN BE DONE TO IMPROVE OXBOW LAKES IN WISCONSIN?

Two options to improve oxbows come to mind: Clean Water Act enforcement and beaver reintroduction. In the latter case, the US Supreme Court recently ruled in the City of Maui v. Hawaii Wildlife Fund that the Clean Water Act can regulate contaminated groundwater discharges to surface waters. Since the Clean Water Act was effective for restoring the Lower Wisconsin River by the early 1980s, now perhaps the federal law can regulate groundwater discharges contaminated with high nitrate concentrations.

While beavers have their critics, beaver dams can expand backwater habitats in floodplains filled with sediment. Beaver dams on small tributaries can establish ponds large enough to support numerous off-channel fish populations (Figure 6). Ben Goldfarb's *Eager: The Surprising, Secret Life of Beavers and Why They Matter* (2018) offers an excellent discussion concerning the ecological value of the North American Beaver *Castor canadensis*.

In 2012 I had reported to WDNR that floodplain lakes appeared to be the most threatened class of lakes in the state. River floodplains require protection and restoration for the important ecological services and habitats they provide. If the late regional author August Derleth (1909–1971) was still around today, he would probably agree. In *Walden West* (1961) Derleth described his frequent visits to a Lower Wisconsin River slough:

> The Spring Slough was the magnet which drew me afternoons and evenings in the spring, and early in the morning hours of many summer days….The Spring Slough teemed with life….The water was never still. Muskrats and turtles broke it; now and then a brown water snake slithered by; flies danced over its surface; sunfish rose, and great northerns came to surface and swirled away…the nostalgic song of the whippoorwills, and, above all, the crying of the frogs—the peepers in a great choir out of the Upper Meadow, the cricket frogs from nearer the slough, the pond frogs conversing across the water, the woods frogs uttering their hoarse croaking out of the tree-grown bottomland to the west-all pulsing and throbbing as in the very rhythm of earth itself…

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Literature Cited

Amoros, C., and G. Bornette. 2002. Connectivity and biocomplexity in waterbodies of riverine floodplains. Freshwater Biology 47:761–776.

Ball, J.R., and D.W. Marshall 1978. Seston characterization of major Wisconsin rivers. Wisconsin Department of Natural Resources Technical Bulletin No. 109.

Bayley, P.B. 1995. Understanding large river: floodplain ecosystems. Bioscience 45:153–158.

Camargo, J.A., A. Alsonso, and A. Salamanca. 2005. Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. Chemosphere 58:1255–1267.

Giblin, S.M, J.N. Houser, J.F. Sullivan, H.A. Langrehr, J.T. Rogala, and B.D. Campbell. 2013. Thresholds in the response of free-floating plant abundance to variation in hydraulic connectivity, nutrients, and macrophyte abundance in a large floodplain river. Wetlands 34:413–425.

Houser, J.N., S.M. Giblin, W.F. James, H.A. Langrehr, J.T. Rogala, J.F. Sullivan, and B.R. Gray. 2013. Nutrient cycling, connectivity and free-floating plant abundance in backwater lakes of the Upper Mississippi River. River Systems 21:71–89.

Killgore, K.J., and J.A. Baker. 1996. Patterns of larval fish abundance in a bottomland hardwood wetland. Wetlands 16:288–295.

Knox, J.C. 2006. Floodplain sedimentation in the Upper Mississippi Valley: natural versus human accelerated. Geomorphology 79:286–310.

Lyons, J. 2005. Fish assemblage structure, composition, and biotic integrity of the Wisconsin River. American Fisheries Society Symposium 45:345–363.

Lyons, J., D.W. Marshall, S. Marcquenski, T. Larson, and J. Unmuth. 2021. Conserving the starhead topminnow *Fundulus dispar* in Wisconsin: 1. current status and threats. American Currents 46:20–26.

Marshall, D.W., and J. Lyons. 2008. Documenting and halting declines of nongame fishes in southern Wisconsin. Pages 171–181 *In*: D. M. Waller and T.R. Rooney (editors), The Vanishing Present: Wisconsin's Changing Lands, Waters, and Wildlife. The University of Chicago Press. 178 pp.

Marshall, D.W., J. Lyons, S. Marcquenski, T. Larson, and J. Unmuth. 2021. Conserving the starhead topminnow *Fundulus dispar* in Wisconsin: 2. Conservation aquaculture. American Currents 46:4–9.

Miyazono, S., J.N. Aycock, L.E. Miranda, and T.E. Tietjen. 2010. Assemblage patterns of fish functional groups relative to habitat connectivity and conditions in floodplain lakes. Ecology of Freshwater Fish 19:578–585.

Opperman, J.J., R. Luster, B.A. McKenney, M. Roberts, and A.W. Meadows. 2010. Ecologically functional floodplains: connectivity, flow regime and scale. JAWRA 46:211–226.

Roach, K.A., J.H. Thorp, and M.D. Delong. 2009. Influence of lateral gradients of hydrologic connectivity on trophic positions of fishes in the Upper Mississippi River. Freshwater Biology 54:607–620.

Slipke, J.W., S.M. Sammons, and M.J. Maceina. 2005. Importance of the connectivity of backwater areas for fish production in Demopolis Reservoir, Alabama. Journal of Freshwater Ecology 20:479–485.