A FISHERY BIOLOGIST'S YEAR ON THE LOWER WISCONSIN RIVER

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Large Midwestern rivers are some of the best places in North America to encounter high fish diversity and unusual species. The problem is, compared to smaller streams and lakes, the fishes of these large rivers are hard to see or catch. The water is typically fairly turbid, and opportunities for viewing fishes from the banks or from in the water are usually limited. A canoe or boat is necessary to visit many habitats. Even then, many species occur in deep or fast water, and to capture them requires specialized gear only available to professional biologists. The small seines, minnow traps, dip nets, and angling rigs used by most fish enthusiasts will yield only a subset of the wide range of species present, and many of the most interesting species will remain out of reach.

I am fortunate that as a professional biologist, I have been able to collect and study the fishes of many large rivers. I had a nearly 33-year career as a fisheries research scientist for the Wisconsin Department of Natural Resources (WDNR) before retiring in 2017. In those years, I had projects throughout the state encompassing the smallest intermittent creeks up to the Mississippi River and little inland ponds up to Lake Superior. I surveyed every large river in the state, and I was able to visit large rivers in many other states and countries as well. But the habitat I have worked on and enjoyed the most is the Lower Wisconsin River (LWR) in southwestern Wisconsin. This 92-mile stretch, from the Prairie du Sac Dam northwest of Madison to the mouth at the Mississippi River (Figure 1), is one of the highest quality, large, lowland, warmwater rivers remaining in the United States (Lyons et al. 2001; Lyons 2005; Weigel et al. 2006). The LWR is free flowing, with no significant pollution discharges, and it has a largely intact and only lightly developed floodplain (Figure 2). The unmodified channel is wide, shallow, and braided (Figure 3), and unsuitable for navigation by anything other than shallow-draft boats, canoes, and kayaks. The flora and fauna are highly diverse and contain many rare species. At least 98 different fish species are present, and the river has one of the best sport fisheries in the state (Rasmussen et al. 1994; Lyons 2005). Recreational use is substantial (Figure 4). In 1989, the LWR was designated as the first and only Wisconsin State Riverway, and just last year the riparian and floodplain area was designated as a wetland of global significance by the Ramsar International Convention, one of only 41 such wetlands in the United States (Figure 5).

I spent much of my career at the WDNR surveying fishes and conducting research on the LWR in both the main channel and the floodplain. I carried out many different studies focusing on different species and habitats throughout the length of the LWR. I continue to do research there through my UW Zoological Museum position, and I also spend much of my free time exploring the river and its

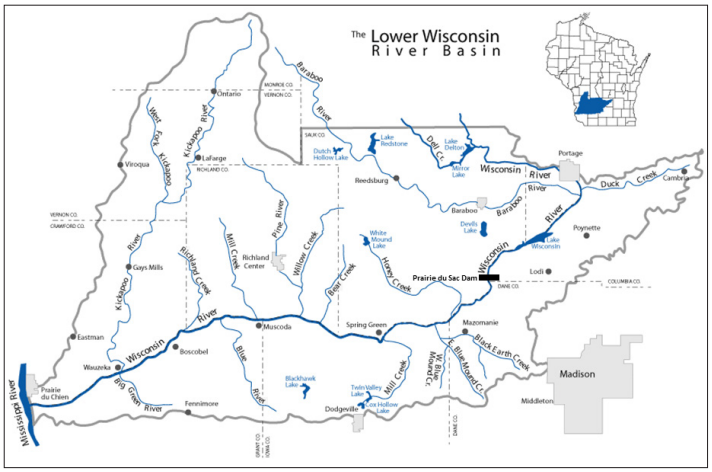

Figure 1. Map of the Lower Wisconsin River Basin showing locations mentioned in the text. The LWR as used in this article begins at the Prairie du Sac Dam. Map courtesy of University of Wisconsin Extension.

Figure 2. A view of the LWR looking downstream from Cactus Bluff near the town of Mazomanie.

All photos by the author.

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Figure 3. The LWR is a wide shallow river filled with sandbars.

Figure 4. Paddlers wait out a sudden downpour on the LWR. Canoeing and kayaking are very popular on the LWR.

Figure 5. Bakkens Pond, a high-quality floodplain lake along the LWR near the town of Spring Green. The main channel is behind the line of trees in the background.

Figure 6. The tailwater of the Prairie du Sac Dam on a cold December day, an important overwintering habitat for many fishes.

Figure 7. Four of the most important sport fishes in the main channel of the LWR. From upper left in clockwise order: Channel Catfish, Smallmouth Bass, Walleye, and Sauger.

Figure 8. Three permanent residents of the Prairie du Sac tailwater. From top: Lake Sturgeon, Paddlefish, and Silver Lamprey.

environs. I've gotten to know the LWR well. In this article, I describe a typical year of fish activity and fish sampling on the LWR. I've consolidated over 35 years of experiences into one to give readers a comprehensive overview of what the river fish community looks like, how it changes with the seasons, and what a fisheries biologist does to understand and protect the fish fauna.

WINTER

The LWR is an inhospitable place in the winter, and it's really difficult then to sample fishes in the river and learn what they're up to. The backwaters are frozen over and the main channel is fringed with ice (Figure 6). Access points are often blocked with snow. As a biologist, I generally didn't sample the river during the winter. It was just too difficult. But I could infer the winter habitats and habits of some species based on where they were in late fall and then again in early spring, presuming that large-scale movements were unlikely during the winter. And radio-tagging studies gave additional insights. The five most important sportfish species in the main channel of the river are Channel Catfish *Ictalurus punctatus,* Flathead Catfish *Pylodictis olivaris,* Smallmouth Bass *Micropterus dolomieu,* Sauger *Sander canadensis,* and Walleye *S. vitreus* (Figure 7). Years of targeted surveys coupled with tagging studies indicate that these species, which from late April through early October are spread out over the entire length of LWR, undertake migrations to specific winter habitats in the fall (Rasmussen et al. 1994; Lyons and Welke 1996; Pellett et al. 1998; Fago 1999; Lyons 2003; Lyons and Oele 2018; WDNR unpublished data). They are looking for deep, slow moving areas. Because the LWR is a wide shallow river, such habitats are rare and limited to the tailwater immediately below the Prairie du Sac Dam, four large scour holes associated with old wing dams or bridges within two miles of the dam, and a few smaller and shallower scour holes further down river. Consequently, these five species migrate to very specific areas each fall. Those fishes that occur in the upper half of the LWR tend to migrate upstream to deep water near the dam, while the individuals that occur in the lower half tend to migrate downstream to the Mississippi River, which has many areas of deep water, but some individuals migrate from near the dam all the way to the Mississippi (Fago 1999; WDNR unpublished data). As a result of these migrations, during the winter many fish have left the LWR, and most of those that remain are found near the Prairie du Sac Dam. The two catfishes and the Smallmouth Bass become very inactive and lay behind or underneath boulders and logs on the bottom (Lyons and Kanehl 2002); the catfishes are so quiescent that scuba divers can easily catch them by hand (Hawkinson and Grunwald 1979; WDNR unpublished data). However, the Sauger and Walleye remain somewhat active and continue feeding, albeit at a low level, and a few hardy anglers catch them throughout the winter.

But what about the many other fishes in the LWR? Three species, Lake Sturgeon *Acipenser fulvescens,* Paddlefish *Polyodon spathula,* and Silver Lamprey *Ichthyomyzon unicuspis*—which is parasitic on the Lake Sturgeon and especially the Paddlefish—appear to remain in the vicinity of the dam year-round, including the winter (Lyons 1993; Runstrom et al. 2001; Knights et al. 2002; Cochran et al. 2003; Zigler et al. 2003; Lyons and Stewart 2014; Cochran and Lyons 2016) (Figure 8). The deep, slow-moving water of the tailwater, enriched with zooplankton from Lake Wisconsin (the reservoir above the dam) appears to provide ideal conditions for their growth and survival throughout the year. The Silver Lampreys probably spawn in gravel areas not far below the dam during the spring and then die, and their larvae (ammocoetes) then reside in marginal silty and sandy areas below the dam for several years before transforming into their parasitic form and attaching to their hosts (Cochran and Lyons 2016). Some Lake Sturgeon and Paddlefish appear to move downstream 3–7 miles to a series of shallow gravel shoals near the town of Mazomanie to spawn for a brief period in the spring (Knights et al. 2002; Zigler et al. 2003; Lyons et al. 2016). From there, most individuals return to the tailwater for the rest of the year, but a few continue downstream to the Mississippi River, where they remain until at least the following spring.

As for the dozens of other main-channel species, we just don't know what they do for the winter. The tailwater of the Prairie du Sac Dam provides excellent year-round habitat for many different species, and some individuals no doubt spend all or most of the year there. But for most of these species, there is no evidence for a major movement into the dam area during the fall, suggesting that many individuals remain in areas further downstream during the winter. Whether they occupy the same fast-flowing microhabitats as they do in the summer, or whether they move into slower and more sheltered areas in the channel, or even into the floodplain backwaters and sloughs, is unknown.

Those species that occupy the floodplain backwaters and sloughs during the summer appear to remain in the floodplain during the winter, but beyond that, their specific winter habitats in the LWR are a mystery. Studies from the Mississippi River indicate that Bluegill *Lepomis macrochirus,* Black Crappie *Pomoxis nigromaculatus,* and other members of the sunfish family (Centrarchidae) seek out specific off-channel areas that have minimal current and relatively high dissolved oxygen during winter (Knights et al. 1995; Johnson et al. 1998; WDNR unpublished data) (Figure 9). Such habitats tend to be scarce in the LWR (and the Mississippi). Many LWR off-channel areas may have current during high flows or become stagnant and oxygen depleted when flows are lower and are thus unsuitable. In the LWR, anglers catch many Bluegill and Black Crappie as well as Largemouth Bass *Micropterus salmoides* and Northern Pike *Esox lucius* through the ice in certain sloughs and floodplain lakes between Spring Green and Boscobel, suggesting that these may be important overwintering areas.

Figure 9. Four of the most important sport fishes of the backwaters and lakes of the floodplain of the LWR. From upper left in clockwise order: Bluegill, Black Crappie, Northern Pike, and Largemouth Bass.

Figure 10. Four fishes that spawn in large numbers on the gravel shoals in the LWR near the town of Mazomanie. From upper left in clockwise order: Quillback, male Shorthead Redhorse, Shovelnose Sturgeon, and male Blue Sucker.

Figure 11. A large female Walleye of about 29 inches and 8 pounds caught in April that probably had spawned a few days earlier. Full of eggs, this fish may have exceeded 10 pounds.

SPRING

My pulse always quickens once the snow begins to melt and the LWR starts to open up in late March. Finally, it's time to get back on the water. But as a biologist, early spring sampling is always a "best of times, worst of times" proposition. When the sun is shining and the weather is mild, it's a delight. Fish are moving again and are in the shallows where they are vulnerable to trap netting and boat electrofishing. Large schools of spawning Quillback *Carpiodes cyprinus,* Smallmouth Buffalo *Ictiobus bubalus,* and Shorthead Redhorse *Moxostoma macrolepidotum* are on the gravel shoals, along with spectacular Blue Sucker *Cycleptus elongatus* (Lyons et al. 2016) (Figure 10). This is the time of year when really large fish can be encountered—Gizzard Shad *Dorosoma cepedianum* over 3 pounds, Smallmouth Buffalo over 20, and Walleye over 8 (Figure 11). Anglers you meet at the boat landings who have seen you catching all these fish inevitably comment, "I wish I had your job," and I completely understand their sentiments. But when the weather is bad, which is much more typical of the early spring, with intense cold, high winds, sleet or snow, and when flood flows hamper sampling effectiveness, being on the river can be absolutely miserable. You're so wrapped up in heavy layers of long underwear, thick clothes, hats, gloves, float coats, and waders to keep dry and warm that you move like Frankenstein's monster. The boat deck is covered with ice, and slips and falls are common. Your hands are raw from immersion in water just above freezing to grab fish for measuring, and the soaking wet data sheets tear as you try to write on them, despite using special "Rite in the Rain" paper. No one has much fun, and I mutter to myself, "I wish I had your job," as I survey the empty boat landing and think of the anglers sitting at home in their warm dry houses.

Figure 12. Four small fishes that live and spawn in the backwaters and lakes of the floodplain of the LWR. From top: male Starhead Topminnow, male Iowa Darter, Weed Shiner, and Lake Chubsucker.

Spring is the time of movement and spawning for all the fishes in the LWR. Walleye and Sauger spawn below the dam and disperse downstream in April (Lyons and Oele 2018). Many fish that had wintered in the Mississippi River begin to return to the LWR (Pellett et al. 1996; Fago 1999; WDNR unpublished data). In April and May, some Mississippi River species, particularly Shovelnose Sturgeon *Scaphirhynchus platorynchus,* move 85 miles or more up the LWR to join resident fishes to spawn in the gravel shoals near Mazomanie (Lyons et al. 2016). Their eggs hatch out a week or two later, and the larvae drift all the way back downstream to the Mississippi where they spend their first few years of life as juveniles (Pracheil et al. 2019). As the weather warms and May progresses into June, Smallmouth Bass build nests in shallow shoreline eddies along the main channel, and Channel and Flathead catfish move under submerged logs for spawning (Pellett 1995; WDNR unpublished data). In the floodplain, Bluegill, Black Crappie, and Largemouth Bass build nests along backwater and slough edges. From late May through July, Starhead Topminnow *Fundulus dispar,* Iowa Darter

Figure 13. Four common small minnows of the main channel of the LWR. From top: male Spotfin Shiner, Emerald Shiner, Sand Shiner, Mississippi Silvery Minnow.

Figure 14. Four small fishes found in areas of strong current in the main channel of the LWR. From top to bottom: Shoal Chub, Western Sand Darter, Silver Chub, River Darter.

Etheostoma exile, Lake Chubsucker *Erimyzon sucetta,* Weed Shiner *Notropis texanus,* and other small fishes lay their eggs on aquatic plants in the sloughs (Figure 12). Back in the main channel, Spotfin Shiners *Cyprinella spiloptera* gather in small groups to lay their eggs in cracks in the wood of downed trees, while huge schools of Emerald *Notropis atherinoides,* River *N. blennius,* Sand *N. stramineus,* and "Channel" *N.* cf. *wickliffi* shiners, and Mississippi Silvery Minnow *Hybognathus nuchalis* spawn by broadcasting their eggs into the water column or onto the bottom in shallow sandy areas with current (Figure 13). All the predatory fishes in the river key in on these spawning aggregations, and anglers in the know have excellent fishing.

With all the fish activity, late spring and early summer is really a magical time of the year, and it would be my favorite if not for the bugs. At times from late May through early August, biting insects can be almost unbearable on the LWR. In shaded areas on the floodplain during the day and everywhere in the evening, the mosquitos can be relentless. In sunny open areas the black flies often take over, especially near the rocky shoals where their larvae live. And on warm days, any exposed wet skin is a target for fast-biting and persistent sand flies, horse flies, and deer flies. It can be maddening. Every rose has its thorn, I guess.

The other non-fish animals of the LWR aren't nearly so disagreeable, and spring also gets them more active and visible. Seeing a wide variety of wildlife is an excellent fringe benefit for working on the river. Among the herptiles, three species of map turtle, two of softshell turtle, and the Northern Water Snake can be regularly observed in the main channel. I particularly remember one April day when I rounded a bend and saw well over 100 softshell turtles of all sizes sunning themselves on a small sandy bank. As soon as they saw me, they rushed back into the water, making a huge commotion. Painted, Blanding's, and Northern Snapping turtles and a wide range of frogs, toads, and salamanders occur on the floodplain. Birdlife is diverse, and many fish-eating varieties are common including Great Blue Heron, Belted Kingfisher, Common and Red-breasted Mergansers, Double-crested Cormorant, Bald Eagle, Osprey, and White Pelican. Bald Eagles would sometimes trail our shocking boat to pick up any fish we'd stunned but missed netting. In the floodplain forests, the majestic Pileated Woodpecker and the beautiful and rare Prothonotary Warbler can often be found. Large mammals commonly observed on the LWR are Whitetail Deer, Muskrat, and Beaver, with River Otter seen sporadically.

SUMMER

By July, fish reproduction is done or winding down, and most species have settled into their summer habitats and are busy feeding and growing. The spawning aggregations of the spring have dispersed, and fishes are now found spread out over the main channel and the floodplain. As their eggs hatch, young of the year fish begin to show up in increasing numbers, and the shallows are full of countless thousands of small fishes and the many larger predators chasing them. It's a great time to be on the river.

With the low water of the summer, much of the channel is accessible to wading, and seining and dip netting yield a variety of in-

Figure 15. The bottom trawl being set over the bow of the boat. The green net is the main body of the trawl and the wooden boards on the right and left are the trawl "doors," which keep the trawl open as it is pulled along the bottom.

teresting minnows and darters. Two of the highlights are the Shoal Chub *Macrhybopsis hyostoma* and Western Sand Darter *Ammocrypta clara* (Figure 14). But some areas remain too deep and fast to be sampled effectively with seines or boat electrofishing, and I've always wondered what they contained. In 2011–2013 I finally got the chance to find out when I was funded to do a small-mesh trawling survey of the LWR and adjacent areas of the Mississippi River.

Trawling in a river out of a small boat is a challenge, but it provides information on fish diversity and distribution that can't be obtained any other way. I used a trawl design and protocol developed by the Missouri Department of Conservation (Herzog et al. 2005). For safety, the trawl is deployed off the bow of a flat-bottomed jonboat while the boat is driven in reverse downstream (Figure 15). It's an awkward and somewhat inefficient approach, but it prevents the boat from swamping when you get hung-up on the bottom, which happens regularly. Freeing a snagged trawl is never easy, and I did completely lose one trawl to a huge sunken tree on the LWR in 2012. The trawl is set, retrieved, and pulled off of snags by hand, and after a full day of trawling, you're beat.

But all the hard work is worth it when the trawl comes up on the deck, and you see fish that are tough to catch any other way. On the LWR, the trawl caught hundreds of just-hatched Channel Catfish and Freshwater Drum *Aplodinotus grunniens*. Some were no longer than a fingernail and must have been only a day or two old. Over the course of the summer, you could watch the average size of the catfish and drum increase as the fish grew. The most numerous minnows in the trawl were Sand Shiner and Channel Shiner, which were also common in shallower areas, but the trawl also yielded species rarely seen in the shallows such as Silver Chub *M. storeriana* and River Darter *Percina shumardi* (Figure 14). And once in a while you'd be surprised by a full-sized Shovelnose Sturgeon or Blue Sucker.

The low water of summer is also the best time to assess the river fish community with the large-river Index of Biotic Integrity (IBI). The large-river IBI employs boat electrofishing to sample the main-channel shallow-water fish community and then uses various quantitative metrics to infer the relative condition of the community (Lyons et al. 2001). Each summer I would sample 10 one-mile stretches over the entire length of the LWR to get a picture of the general health of the river. The sampling was not easy. At low

Figure 16. Four unusual fishes taken regularly from the LWR during late summer electroshocking. From top to bottom: Mooneye, Longnose Gar, Shortnose Gar, Crystal Darter.

water the river is barely navigable even in a shallow-draft "mini-boom" electroshocker. The boat constantly ran aground, and we'd have to hop into the water and push it off. Once or twice I really wondered if we could move our boat or if we'd have to abandon it and wait days or weeks until the water levels rose enough to free it from the endless shallow sand flats. Fish were concentrated in log jams and brush piles along the shore, and we'd battle the strong and irregular currents to get the boat in amongst the downed trees and logs, crashing through tangled branches full of spider webs and battering into hidden stumps just under the surface. When we weren't struggling amongst the trees, we were out in the open frying in the merciless August sun in an aluminum boat in which the decks and gunwales got hot enough to burn your skin if you weren't careful. At the end of the day, the crew and I would look and feel pretty bedraggled.

But the fishes were amazing and worth all the trouble. Big Smallmouth Bass, Sauger, Walleye, and catfish, and incredible numbers of Blue Sucker and various redhorses, buffalos, and carpsuckers were routine. Mooneye *Hiodon tergisus* and Longnose *Lepisosteus osseus* and Shortnose gars *L. platostomus* appeared regularly (Figure 16). Occasionally a Crystal Darter *Crystallaria asprella* would come aboard. Unlike many other large rivers in the Midwest, the LWR still contains all the elements of an intact and functioning fish community, and it was a joy to see. Each year, IBI scores were always high and ratings were good to excellent, indicating that the LWR remained in good shape (Lyons 2005).

FALL

Early fall is the nicest time of year on the LWR. The heat and humidity of the summer have broken but it's still pleasantly warm. Biting insects are much reduced. Water levels remain low and water temperatures warm, and wading remains practical and enjoy-

Figure 17. WDNR Fisheries Research Technician Eric Struck holds a 46-inch Muskellunge caught during late October night shocking in the Prairie du Sac Dam tailwater. A wound from a Silver Lamprey is visible on the fish's belly.

able. Young-of-the year fishes are now large enough to be caught and identified easily. Fishes are active and just beginning their movements to winter habitats. It's my favorite time of year to go paddling or fishing on the LWR.

When I was with WDNR, my annual sampling regime on the LWR would end in late October with an assessment of key gamefish populations in the tailwater of the Prairie du Sac Dam. By this time, these gamefish had concentrated in the tailwater for the winter, but water temperatures were still high enough that they remained active and feeding. Electrofishing in the shallows at night was a highly effective way to get a picture of relative abundance, size structure, and success of reproduction for that year. In general, I wanted to track juvenile gamefish numbers so that I had an idea of what the sport fishery would be like in subsequent years. And I had a specific goal to understand the environmental factors that determined whether it had been a good year or a poor year for the reproduction of Sauger and Walleye.

This fall electrofishing was always interesting and sometimes challenging. By late October, the weather was unpredictable. Some years it would be mild and pleasant, but in others it would be cold and wet and just as uncomfortable as it could be in the early spring. Sampling at night gave a really different perspective, and it was fascinating and a bit eerie to watch all sorts of fishes roll up in the headlights at the front of the shocking boat. Although we targeted Sauger, Walleye, Largemouth Bass, Smallmouth Bass, Northern Pike, and Muskellunge *Esox masquinongy,* we saw dozens of different species including large Paddlefish, Lake Sturgeon, catfishes, and buffalos. The Muskellunge in the tailwater were the only non-self-sustaining fish population in the LWR. They were stocked above the dam, and some individuals passed through the dam spill gates during high flows and took up residence in the tailwater. Although they did not reproduce successfully in the LWR, they survived and grew well, and a popular sport fishery for them developed. We'd catch numerous trophy muskies every night we were out (Figure 17).

I did the fall shocking for 30 years, from 1987 through 2016, and WDNR biologists have continued the survey since I retired. Interestingly, despite all these years of data, I never could tease out exactly what was driving the success of Sauger and Walleye reproduction. There was huge variation in reproductive success, with good years producing over 100 times more young-of-the-year than poor years, but what drove this variation remained unclear. After the first few years of the monitoring, it looked like river flows were paramount, with higher flows associated with more young-of-year fish produced (Lyons and Welke 1996). But with a few more years of data, the effects of high and low flows were less obvious—some high-flow years yielded lower numbers and some low-flow years yielded higher numbers—and it appeared that perhaps water temperature might be key, with warmer years correlated with high numbers of young-of-the-year fish (Lyons 2003). But with the full 30 years of data, neither flow nor temperature was a strong predictor of reproductive success for either species (Lyons and Oele 2018). There were some weak correlations, but most of the variation in young-of-year numbers remained unexplained. It appeared that the reproductive success of Sauger and Walleye was driven by a complex mix of physical and biological conditions in the LWR, and no one factor guaranteed reproductive success or failure. This illustrates a common phenomenon in science: sometimes as you collect more data, you end up understanding a question less than you did initially. But having the additional data to reveal that the situation is more complicated than you initially thought is critically important. So, my 30 years of effort were not in vain.

With the completion of the late October sampling, my time on the river would usually end for the year. I'd retire to my office to work up the reams of data I'd collected, write reports, and dream of the spring and my next chance to get out on the LWR.

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References Cited

Cochran, P.A., and J. Lyons. 2016. The silver lamprey and the paddlefish. Pages 214–233 *in* A. Orlov and R. Beamish, editors. Jawless fishes of the world. Volume 2. Cambridge Scholars Publishing.

Cochran, P.A., J. Lyons, and M.R. Gehl. 2003. Parasitic attachments by overwintering silver lampreys, *Ichthyomyzon unicuspis,* and chestnut lampreys, *Ichthyomyzon castaneus*. Environmental Biology of Fishes 68:65–71.

Fago, D. 1999. Movement of channel catfish in the lower Wisconsin River and Pools Numbers 10 and 11 of the Mississippi River using radiotelemetry. American Fisheries Society Symposium 24:177–185.

Hawkinson, B., and G. Grunwald. 1979. Observation of a wintertime concentration of catfish in the Mississippi River. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries, St. Paul, Investigational Report 365.

Herzog, D.P., V.A Barko, J.S. Scheide, R.A. Hrabik, and D.E. Ostendorf. 2005. Efficacy of a benthic trawl for sampling small-bodied fishes in large river systems. North American Journal of Fisheries Management 25:594–603.

Johnson, B.L., B.C. Knights, J.W. Barko, R.F. Gaugush, D.M. Soballe, and W.F. James. 1998. Estimating flow rates to optimize winter habitat for centrarchid fish in Mississippi River (USA) backwaters. River Research and Applications 14:499–510.

Knights, B.C., B.L. Johnson, and M.B. Sandheinrich. 1995. Responses of bluegills and black crappies to dissolved oxygen, temperature, and current in backwater lakes of the Upper Mississippi River during winter. North American Journal of Fisheries Management 15:390–399.

Knights, B.C., J.M. Vallazza, S.J. Zigler, and M.R. Dewey. 2002. Habitat and movement of lake sturgeon in the upper Mississippi River system, USA. Transactions of the American Fisheries Society 131:507–522.

Lyons, J. 1993. Status and biology of the paddlefish (*Polyodon spathula*) in the lower Wisconsin River. Transactions of the Wisconsin Academy of Science, Arts, and Letters 81:123–135.

Lyons, J. 2003. Recruitment patterns of walleye and sauger in the lower Wisconsin River. Pages 79–80 *in* T. P. Barry and J. A. Malison, editors. Proceedings of Percis III, the Third International Percid Fish Symposium, Madison, Wisconsin, July 20–24, 2003. University of Wisconsin Sea Grant Institute, Madison.

Lyons, J. 2005. Fish assemblage structure, composition, and biotic integrity of the Wisconsin River. Pages 345–363 *in* R. Calamusso, R. Hughes, and J. Rinne, editors. Historical changes in large river fish assemblages of North America. American Fisheries Society Symposium Number 45, Bethesda, Maryland.

Lyons, J., and P. Kanehl. 2002. Seasonal movements of smallmouth bass in streams. Pages 149–160 *in* M. Ridgway and D. P. Philipp, editors. Black bass: ecology, conservation, and management. American Fisheries Society Symposium Number 31, Bethesda, Maryland.

Lyons, J., and D.L. Oele. 2018. Sauger and walleye year-class formation in the Lower Wisconsin River, 1987–2016. North American Journal of Fisheries Management 38:842–855.

Lyons, J., R.R. Piette, and K.W. Niermeyer. 2001. Development, validation, and application of a fish-based index of biotic integrity for Wisconsin's large warmwater rivers. Transactions of the American Fisheries Society 130:1077–1094.

Lyons, J., and J.S. Stewart. 2014. Predicted effects of future climate warming on thermal habitat suitability for lake sturgeon (*Acipenser fulvescens,* Rafinesque, 1817) in rivers in Wisconsin, USA. Journal of Applied Ichthyology 30:1508–1513.

Lyons, J., D. Walchak, J. Haglund, P. Kanehl, and B. Pracheil. 2016. Habitat use and population characteristics of potentially spawning shovelnose sturgeon *Scaphirhynchus platorynchus* (Rafinesque, 1820), blue sucker *Cycleptus elongatus* (Lesueur, 1817), and associated species in the lower Wisconsin River, USA. Journal of Applied Ichthyology 32:1003–1015.

Lyons, J., and K. Welke. 1996. Abundance and growth of young-of-year walleye (*Stizostedion vitreum*) and sauger (*S. canadense*) in Pool 10, upper Mississippi River, and at Prairie du Sac dam, lower Wisconsin River, 1987–1994. Journal of Freshwater Ecology 11:39–50.

Pellett, T.D. 1995. Preliminary observations on the spawning and early life history of the channel catfish from the lower Wisconsin River with recommendations for further study. Wisconsin Department of Natural Resources, Madison, Research Report 166.

Pellett, T.D., G.J. Van Dyck, and J.V. Adams. 1998. Seasonal migration and homing of channel catfish in the lower Wisconsin River, Wisconsin. North American Journal of Fisheries Management 18:85–95.

Pracheil, B.M., J. Lyons, E.J. Hamann, P.H. Short, and P.B. McIntyre. 2019. Shovelnose sturgeon population connectivity throughout life history in a large river mainstem and tributary: a case study from the Mississippi and Wisconsin rivers. Ecology of Freshwater Fish 28:20–32.

Rasmussen, P.W., J.M.L. Unmuth, J. Lyons, and G.J. Van Dyck. 1994. A creel survey of the Lower Wisconsin River, 1990–1991. Wisconsin Department of Natural Resources, Madison, Research Report No. 160.

Runstrom, A.L., B. Vondracek, and C.A. Jennings. 2001. Population statistics for paddlefish in the Wisconsin River. Transactions of the American Fisheries Society 130:546–556.

Weigel, B.M., J. Lyons, and P.W. Rasmussen. 2006. Fish assemblages and biotic integrity of a highly modified floodplain river, the Upper Mississippi, and a large relatively unimpacted tributary, the lower Wisconsin. River Research and Applications 22:923–936.

Zigler, S.J., M.R. Dewey, B.C. Knights, A.L. Runstrom, and M.T. Steingraeber. 2003. Movement and habitat use by radio-tagged paddlefish in the Upper Mississippi River and tributaries. North American Journal of Fisheries Management 23:189–205.