CONSERVING THE STARHEAD TOPMINNOW *FUNDULUS DISPAR* IN WISCONSIN: 1. CURRENT STATUS AND THREATS

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INTRODUCTION

We love dickey fishes, to borrow and adapt a term from the bird-watching community. Among birders, dickey birds are small, inconspicuous, non-descript, and often hard-to-identify species that the general public hardly notices or cares about. In the fish world, most herrings, minnows, madtoms, mudminnows, killifishes and topminnows, sticklebacks, pirate perch, troutperches, livebearers, silversides, sculpins, darters, and gobies would qualify as dickey fishes. Few people, readers of *American Currents* excepted, are aware of them and even fewer can tell them apart or think much about their existence. Yet like dickey birds, dickey fishes are essential to the health and functioning of the ecosystems they inhabit. Conserving their populations is necessary if we are to have thriving populations of the sport and commercial fishes and other aquatic fauna that the public does care about.

The five of us are retirees from the Wisconsin Department of Natural Resources (WDNR), the agency primarily responsible for the conservation and management of fishes and rivers and lakes in Wisconsin. While with WDNR, we all worked on various projects to protect and improve aquatic ecosystems and their fish populations, but our focus was economically important species, mainly sport fishes. We tried to incorporate smaller, "non-game" or "forage" (i.e., dickey) fishes into our projects, but we never had sufficient time to do them justice. Upon retirement, none of us wanted to stop working on aquatic conservation issues, and, with no institutional constraints, we decided we should focus on helping some of our favorite dickey fishes. Top of the list was the Starhead Topminnow *Fundulus dispar*, an inconspicuous yet handsome and fascinating species (Figure 1).

The Starhead Topminnow is rare enough in Wisconsin to be on the state Endangered Species list, but despite that, it has never gotten much attention or study. Nor has it seen any specific management actions to increase its distribution or abundance. It was always a special treat when we encountered this uncommon species during our surveys. Its stronghold in the state is one of our favorite aquatic environments, the sloughs, backwaters, oxbows, and floodplain lakes of the Lower Wisconsin River, which for simplicity we refer to collectively as "sloughs" going forward. The Lower Wisconsin River is one of the longest free-flowing large rivers in the Midwest, and much of the riparian corridor remains in good shape, with scenic bluffs and upland forests and prairies, extensive bottomland forests, swamps, and marshes, a natural shallow, sandy, and braided channel, and a largely intact flora and fauna. Ninety-eight fish species have been reported

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Figure 1. Starhead Topminnows: adult female (top) and male (middle) (photos by John Lyons) and male in an aquarium (photo by Dave Marshall).

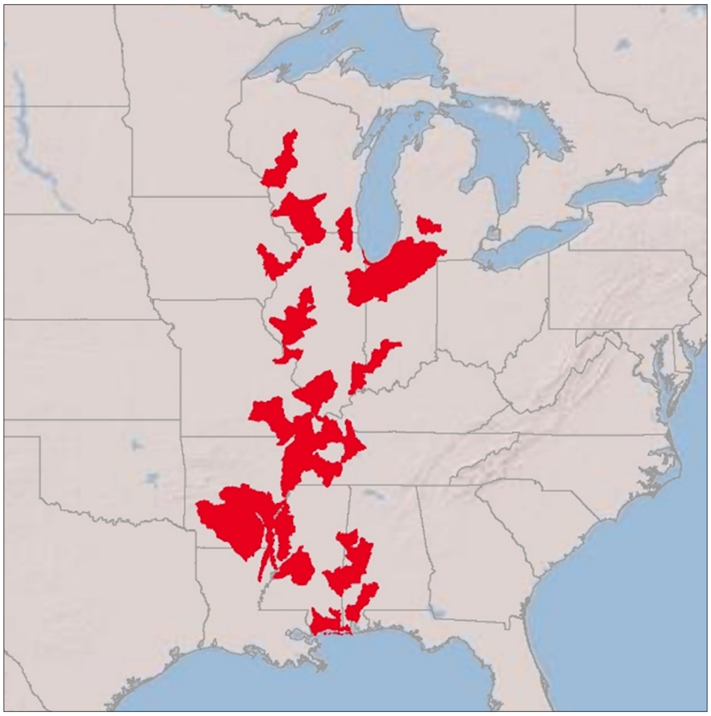


Figure 2. The range the of Starhead Topminnow by river drainage. Map courtesy of Nature Serve (https://www.natureserve.org/, accessed September 12, 2020).

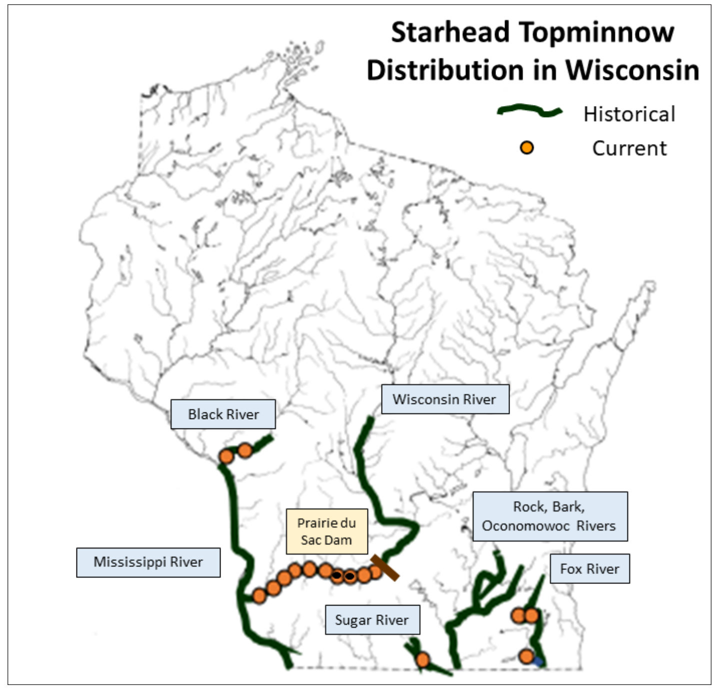


Figure 3. Map of the estimated historical and current distribution of Starhead Topminnow in Wisconsin. The two orange circles with black dots indicate the areas where the specific sloughs mentioned in the text are located.

from this stretch of river, with many restricted to the sloughs (Lyons 2005). In recognition of this high ecosystem and biological diversity and to aid in its protection, the Lower Wisconsin River was designated as the first and only Wisconsin State Riverway in 1989 (https://dnr.wisconsin.gov/topic/lands/lowerwisconsin), and in early 2020, its riparian corridor and floodplain were recognized as a wetland of global significance by the Ramsar International Convention, one of only 41 such wetlands in the United States (https://rsis.ramsar.org/ris/2417).

However, in recent years we have detected a disturbing trend in the some of the sloughs along the Lower Wisconsin. Formerly, they were filled with a wide variety of submerged and floating-leaf aquatic plants, and Starhead Topminnows were often numerous. But now many of these same sloughs have become almost completely covered with a thick layer of duckweed (*Lemna* species) and filamentous algae; large macrophytes have declined, and topminnows have become scarce. The change in aquatic vegetation is associated with a heavy increase in intensive corn cultivation in adjacent floodplain sand terraces. These terraces require major irrigation and fertilization to produce crops, and this type of agriculture has led to elevated nitrate concentrations in the shallow groundwater that feeds the sloughs. Nitrate often drives surges in duckweed and algae (Giblin et al. 2014, Sondergaard et al. 2017) and also threatens the drinking water of some local residents. In a few short years, the Starhead Topminnow's stronghold in Wisconsin has come under threat.

We decided that Starhead Topminnows in the Lower Wisconsin needed help. While we worked with our network of WDNR and other colleagues to publicize and urge a response to excessive nitrate in the groundwater that was entering the sloughs, we understood all too well that the WDNR's ability to affect change in this situation was limited and would take time. We decided that we needed to develop refuge populations elsewhere that could preserve the genetic stock of the Lower Wisconsin and perhaps serve as a source for re-establishing the species there if the nitrate situation got worse before it got better. Specifically, we began an effort to re-establish the Starhead Topminnow above the Prairie du Sac Dam, the upper boundary of the Lower Wisconsin River. Starhead Topminnows were probably once found in the sloughs upstream from the dam, which is a complete barrier to upstream movement, but they are now absent. Many of the upstream sloughs appear to have ideal habitat and do not have adjacent agriculture. And for an endangered species such as the Starhead Topminnow, any expansion of its range would be beneficial to its long-term survival.

This article is the first of three describing our efforts to conserve Starhead Topminnows in Wisconsin. Here, we describe the historical and current status of the species in the state, key attributes of its habitat that are relevant to re-establishment, the threats it faces, and its prospects for the future, with emphasis on the Lower Wisconsin River. In the second article, to be published in a future issue of *American Currents*, we will describe our project to re-establish the species above the Prairie du Sac Dam. This project began in 2018 and will conclude in 2021.

DISTRIBUTION AND STATUS

The Starhead Topminnow has a fragmented range in the central United States, where it is found primarily in the Mississippi River basin. It reaches the northern edge of its range in southern Wisconsin (Figure 2). In the north, the Starhead Topminnow has also been found in small disjunct areas of east-central Iowa, northern Illinois, and northern Indiana in the Mississippi River basin, and northern Indiana and southwestern Michigan in the Lake Michigan basin. Further south, the species has been reported from parts of southern Illinois, southern Indiana, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana in the Mississippi River basin and from Mississippi and Alabama in the Mobile River basin.

The historical distribution of the Starhead Topminnow is poorly known in Wisconsin, and there are few reported collections prior to the 1970s, at which point the species was already quite rare (Becker 1983). Based on current occurrences, the estimated historical extent of suitable habitat, and the distribution of commonly associated fish species, we postulate that Starhead Topminnows were once found in most large-river floodplain corridors and some glacial lakes in the southern third of the state (Figure 3). Specifically, we think Starhead Topminnows were present along the Mississippi River as far north as the Black River, the lower 20 miles or so of the Black River itself, the lower 150–200 miles of the Wisconsin River possibly as far upstream as the historical rapids at Necedah, the Rock River drainage including the Rock proper and the lower Sugar, Bark, and Oconomowoc rivers, and the Fox River up to the city of Waukesha including a key tributary, the Mukwonago River. Within the Fox and Rock drainages, Starhead Topminnows were probably also found in some of the glacial drainage lakes connected to these two rivers. However, it is likely the historical distribution was highly discontinuous and sporadic in all of these river drainages and limited to specific habitats.

At present, Starhead Topminnows are known from only five areas: (1) two sloughs of the Lower Black River; (2) the Mukwonago River, its connected glacial lakes (i.e., Lulu, Eagle Springs, Phantom, Beulah), and the adjacent Fox River in Waukesha County; (3) Camp Lake in Kenosha County in the Fox River drainage; (4) a small stretch of the Lower Sugar River in Rock County; and (5) the Lower Wisconsin River in Sauk, Richland, Crawford, Grant, Iowa, and Dane counties below the Prairie du Sac Dam (Lyons et al. 2000, and our unpublished data). The Lower Wisconsin River has by far the most populations and the highest number of individuals.

We believe that the Starhead Topminnow has declined substantially in distribution and abundance in the nearly 200 years of European settlement of Wisconsin. Many of the land-uses associated with settlement degraded or eliminated Starhead Topminnow habitats, and the populations we see today probably represent only a small fraction of the number that were once present (Becker 1983, Marshall and Lyons 2008). Clearing of the land for timber production and agriculture resulted in massive erosion and siltation that filled many sloughs and backwaters and isolated river channels from their floodplains (Knox 2006). Draining and filling of wetlands, construction of dams, and shoreline urbanization eliminated other sloughs and backwaters. These activities all also lowered the water table, drying out the springs and seeps that we have found to be essential to good Starhead Topminnow habitat in Wisconsin. And the late 19th century introduction and rapid spread of Common Carp *Cyprinus carpio* greatly modified and reduced aquatic plant communities in both riverine and glacial lakes, further eliminating Starhead Topminnow habitats. Becker (1983:764), in his monumental book *Fishes of Wisconsin*, was so concerned about the future survival of the species in the state that he recommended that a "topminnow sanctuary" be established. A logical place for such a sanctuary would be the sloughs of the Lower Wisconsin River.

HABITAT

The Starhead Topminnow is a species of quiet, generally shallow and clear waters with abundant aquatic vegetation (Becker 1983). Diverse and thick growths of submerged and floating-leaf macrophytes are essential and provide hiding cover, a source of food from associated macroinvertebrates, and a substrate for spawning and egg deposition (Taylor and Burr 1997). We surveyed possible Starhead Topminnow habitats from 2007 through 2012 across southern Wisconsin (our unpublished data), and rooted aquatic plants were present at all sites with Starhead Topminnows, with plant densities ranked as "medium" or "high" at 74% of them.

Starhead Topminnows, as their name implies, are usually found near the water surface. They often occur in very shallow water near shore, only centimeters deep. But they can also be found at the surface over deeper water (over 1 meter) as well, the key being hiding cover to avoid avian and aquatic predators. Usually this cover is aquatic vegetation, but it can also be flooded terrestrial vegetation or downed trees and branches. The Starhead Topminnow is rarely observed in open water more than a meter or two away from either the shoreline or some sort of cover.

Water chemistry conditions where Starhead Topminnows occur are highly variable. In the 2007–2012 survey, dissolved oxygen and specific conductance levels at Starhead Topminnow sites ranged from 3.0 to 19.4 mg/l (mean = 8.56) and 32 to 1294 *u*S/cm (mean = 417) respectively (N=102). The wide range of dissolved oxygen levels largely reflected the high densities of macrophytes, the timing of sample collection, and the hydrology of floodplain sloughs rather than the presence of water quality problems. During warm sunny days, photosynthesis from the plants produced supersaturated dissolved oxygen conditions (above 9–10 mg/l), but on cloudy days or at night, plant respiration lowered oxygen values below saturation. High river levels also sometimes reduced dissolved oxygen conditions as described below. Specific conductance levels largely tracked local soil and bedrock features and the presence of groundwater inputs. Very low specific conductance values (less than 100 uS/cm) were found in Black River sloughs that receive large amounts of very soft groundwater. Extremely high specific conductance levels (greater than 1000 uS/cm) were found at some of the southeastern sites in the Fox River drainage that have runoff from urban areas, which is typically high in dissolved substances. Elsewhere, including along the Lower Wisconsin River, intermediate conductivity levels (300 – 600 uS/cm) reflected the local karst geology and groundwater with high calcium carbonate alkalinity. Groundwater is an extremely important feature of all Starhead Topminnow habitats in Wisconsin and appears essential for their survival. Nearly all sites with Starhead Topminnows had substantial and obvious groundwater inputs from seeps, springs, or spring-fed tributaries, and sites without these inputs almost never had Starhead Topminnows. We hypothesize that the groundwater provides a refuge of relatively warm water (typically about 10–11°C [50–52°F] in this part of the state) during Wisconsin's harsh winters, when most waters are ice-covered and near freezing, a key consideration for a species at the northern edge of its range. Groundwater may also provide more stable water levels during droughts.

There are hundreds of sloughs along the Lower Wisconsin River (and the Lower Black and Lower Sugar rivers), but only those relatively few with strong groundwater inputs, diverse and healthy rooted aquatic plant communities, and species-rich fish communities support Starhead Topminnows. The proper groundwater and plant conditions occur when the river floodplain borders an upland area, often a limestone-sandstone bluff or a steep slope leading to a sandy, flat, riverine terrace. In these locations, the floodplain intercepts a massive Driftless Area aquifer (Pfeiffer et al. 2006). Starhead

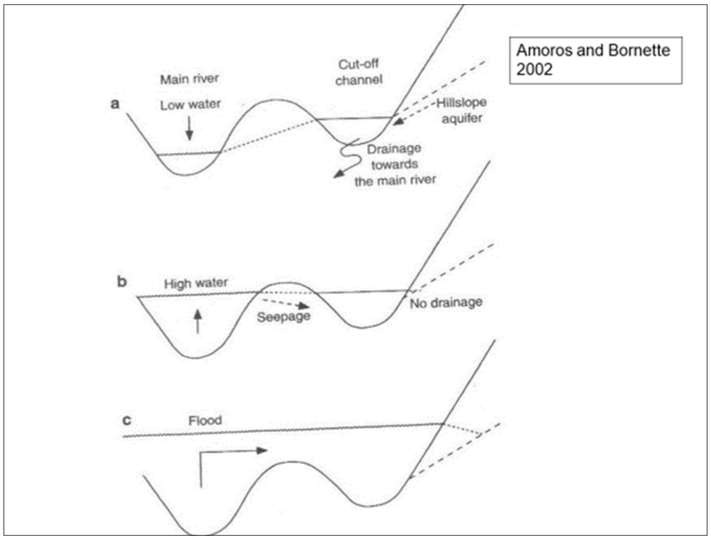


Figure 4. Large river hydrologic changes in slough, backwaters, and floodplain lakes (= cut-off channel) associated with different river stages (from Amoros and Bornette 2002).

Figure 5. Liquid manure being spread on a cultivated field on a sandy riverine terrace along the Lower Wisconsin River near Jones Slough and Norton Slough, just east of the town of Spring Green. (Photo by Dave Marshall)

Topminnows in the Lower Wisconsin share their home with at least 33 species of fish (Table 1). Some are widespread generalists such as Bluegill *Lepomis macrochirus,* Largemouth Bass *Micropterus salmoides*, and Central Mudminnow *Umbra limi,* but others are fellow slough specialists such as Grass Pickerel *Esox americanus vermiculatus*, Pirate Perch *Aphredoderus sayanus*, Warmouth *Lepomis gulosus*, and Lake Chubsucker *Erimyzon sucetta*. (Table 1)

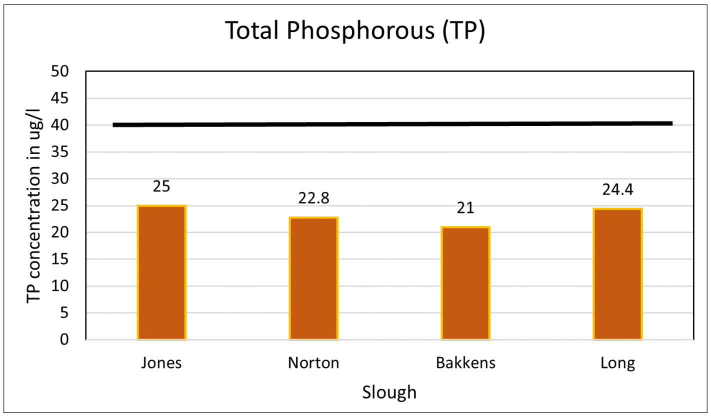
Physical and chemical conditions in the sloughs inhabited by Starhead Topminnows along the Lower Wisconsin River change dramatically depending on river level. At low and average river stages, which occur most often in summer, fall, and winter, groundwater is the primary water source (Figure 4). At this point, the surface of the slough is slightly higher than that of the main channel and water flows from the slough towards the channel. Water in the slough is clear, daytime oxygen levels are high, and pH and conductivity are also relatively high from groundwater. At higher river stages, mainly in the spring, but possible at any time of year after heavy precipitation, the slough is at the same or a lower elevation than the surrounding floodplain, and chemically reduced alluvial groundwater from the floodplain enters the slough, resulting in water quality changes. Dissolved oxygen, pH, and conductivity levels drop, and slough waters become more stained (the main channel of the Wisconsin has stained water). At flood stages, river current temporarily returns to the slough, the water becomes turbid from dissolved and suspended solids, and bottom scouring occurs. Under these conditions, Starhead Topminnows may move into flooded terrestrial areas. For example, in 2007, we observed many Starhead Topminnows swimming over a flooded grass field located over 100 meters from the nearest permanent water. Periodic flooding may facilitate Starhead Topminnow dispersal to other sloughs within the floodplain.

Table 1. Species captured with Starhead Topminnows, ranked by percent frequency of occurrence, from 64 samples along the Lower Wisconsin River sampled in 2009–2012 (our unpublished data).

Common Name	Scientific Name	Percent Frequency
Bluegill	*Lepomis macrochirus*	87.5
Largemouth Bass	*Micropterus salmoides*	73.4
Grass Pickerel	*Esox americanus vermiculatus*	60.9
Central Mudminnow	*Umbra limi*	60.9
Pirate Perch	*Aphredoderus sayanus*	59.4
Warmouth	*Lepomis megalotis*	42.2
Mud Darter	*Etheostoma asprigene*	40.6
Green Sunfish	*Lepomis cyanellus*	26.6
Lake Chubsucker	*Erimyzon sucetta*	23.4
Yellow Bullhead	*Ameiurus nebulosus*	20.3
Brook Silverside	*Labidesthes sicculus*	15.6
Iowa Darter	*Etheostoma exile*	15.6
Johnny Darter	*Etheostoma nigrum*	12.5
Tadpole Madtom	*Noturus gyrinus*	10.9
Pumpkinseed	*Lepomis gibbosus*	10.9

Common Name	Scientific Name	Percent Frequency
Golden Shiner	*Notemigonus crysoleucas*	10.9
Smallmouth Bass	*Micropterus dolomieu*	7.8
Bowfin	*Amia calva*	6.3
Black Crappie	*Pomoxis nigromaculatus*	6.3
Banded Darter	*Etheostoma zonale*	4.7
Northern Pike	*Esox lucius*	4.7
White Sucker	*Catostomus commersonii*	4.7
Yellow Perch	*Perca flavescens*	3.1
Rock Bass	*Ambloplites rupestris*	3.1
Weed Shiner	*Notropis texanus*	3.1

Species found at just one site: Bluntnose Minnow *Pimephales notatus*, Fathead Minnow *Pimephales promelas*, Emerald Shiner *Notropis atherinoides*, Black Bullhead *Ameiurus melas*, Burbot *Lota lota*, Rainbow Darter *Etheostoma caeruleum*, Blackside Darter *Percina maculata*, Walleye *Sander vitreus*



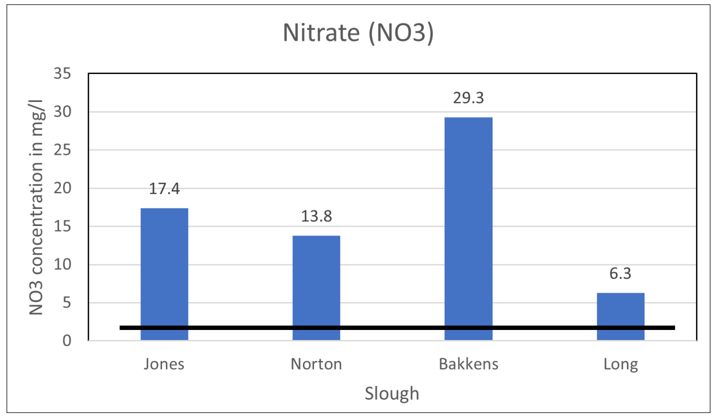


Figure 6. Mean total phosphorous (left) and nitrate (right) concentrations in shallow groundwater wells located between intensively cultivated sandy riverine terraces and four sloughs along the Lower Wisconsin River during 2013–2017. Jones Slough and Norton Slough are near the town of Spring Green, Long Lake is to the west near the town of Lone Rock, and Bakkens Pond is between the two towns. Note the difference in scale; nitrate is measured in milligrams per liter (mg/l), 1000 times more than the micrograms per liter (ug/l) for total phosphorus. Wisconsin's aquatic life water quality standards for non-stratified lakes are shown as dark horizontal lines (40 ug/l codified for total phosphorus; 1.23 mg/l proposed for nitrate).

THREATS

As previously mentioned, habitat eutrophication, that is, high nutrient concentrations causing excessive algae and plant growth, appears to be impacting Starhead Topminnows along the Lower Wisconsin River. Our surveys there in 2007–2012 found Starhead Topminnows in 52 different sloughs. Most had excellent water quality, diverse and healthy plant communities, and a rich fish assemblage at the time of our first visit. However, these favorable conditions soon changed at many sites. During the early 2000s, with corn prices rising, agriculture on the sand terraces adjacent to the Starhead Topminnow habitats began to intensify and become dominated by industrial-scale operations (Figure 5). Growing corn on the nutrient-poor sand terraces requires large amounts of synthetic fertilizer or liquid manure plus spray irrigation. Anything applied to the crop fields quickly enters the shallow groundwater aquifer and moves relatively rapidly through the porous sandy soils towards the river. By 2011, the high levels of nutrients in this groundwater started to reach the nearest sloughs and eutrophication began.

In most freshwater lakes, eutrophication is driven mainly by phosphorus, but in shallow lakes and in sloughs in river floodplains, nitrogen is often the key nutrient (Giblin et al 2014, Sondergaard et al. 2017). Along the Lower Wisconsin River, groundwater samples collected during 2013–2017 from wells located between the intensively cultivated river terraces and four sloughs indicated that nitrogen, primarily nitrate, was much more abundant than phosphorus (Figure 6) and at levels high enough to account for the sudden explosion of thick floating mats of duckweed and filamentous algae (Figure 7). In Jones Slough near the town of Spring Green (Figure 8), this thick mat caused the loss of rooted aquatic plants, declines of dissolved oxygen to stressful levels, and the disappearance of Mud Darter *Etheostoma asprigene* and Iowa Darter *Etheostoma exile*. Nitrate entering from the groundwater may have been at high enough levels to cause direct harm to fishes (Camargo et al. 2005). Further, decaying plant matter coupled with a lack of dissolved oxygen also produced toxic ammonia concentrations on the bottom. Starhead Topminnows did not completely disappear from Jones Slough, but their numbers declined substantially owing to the loss of their preferred plant habitats and due to low dissolved oxygen and high ammonia levels below the floating mats.

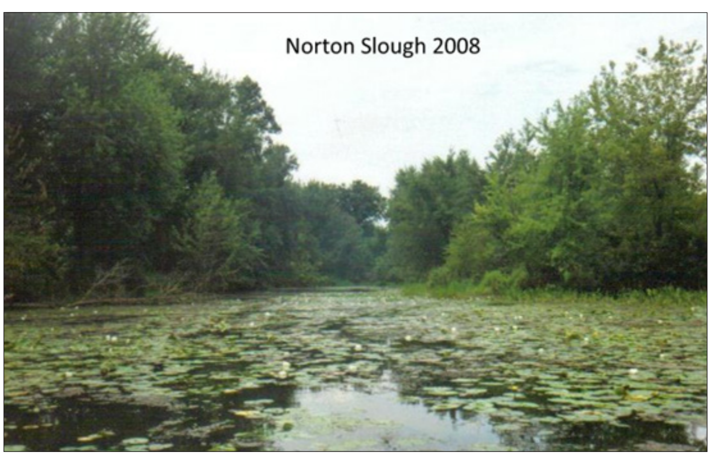


Figure 7. View of Norton Slough, Lower Wisconsin River, near Spring Green. Left: 2008, before nutrient polluted groundwater, with diverse rooted aquatic plants and many Starhead Topminnows. Right: 2011, after nutrient polluted groundwater, covered with a thick mat of floating duckweed and filamentous algae and few Starhead Topminnows. (Photos by Dave Marshall)

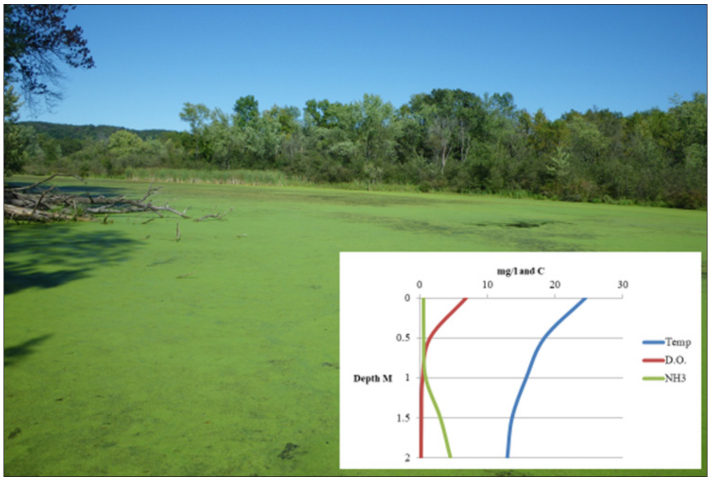


Figure 8. Jones Slough, near the town of Spring Green, after receiving nutrient-polluted groundwater in 2011. Previously the slough had looked similar to Norton Slough in 2008 (Figure 7, left). The insert is a vertical profile of water quality during the summer, showing the disappearance of dissolved oxygen below 0.5 m depth and the increase in ammonia (NH3) below 1 m depth. (Photo by Dave Marshall)

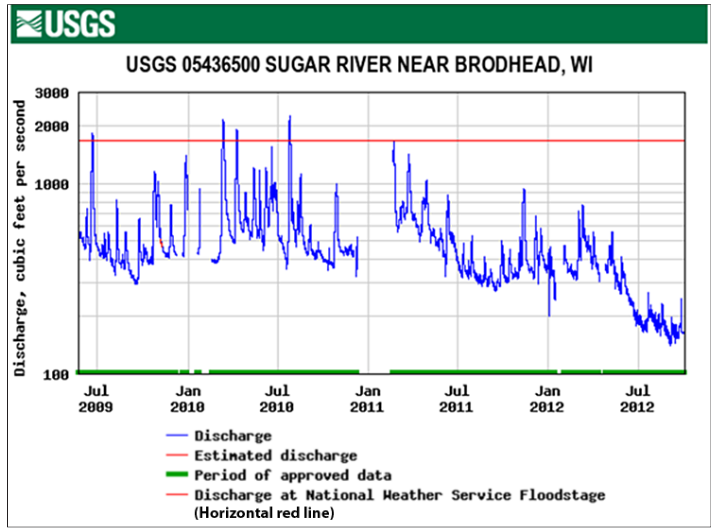


Figure 9. Hydrograph of the Lower Sugar River from the US Geological Survey stream gage at Brodhead, Wisconsin, about 15 kilometers upstream of the area with Starhead Topminnows, from 2009–2012. Four floods (flow peaks above red flood-stage line) occurred in 2009 and 2010, reconnecting isolated sloughs to the river channel. However, a drought occurred in 2012, with flows dropping to about 100 cubic feet per second (cfs), well below the typical level of 500–600 cfs. Consequently, connections with sloughs were broken and many of these habitats dried up.

Habitat loss can take other forms besides aquatic vegetation and water quality changes. In many rivers in southern Wisconsin, including the Sugar and Fox, many years of heavy erosion and siltation from the watershed have led to floodplain accretion (i.e., increase in the elevation of the floodplain relative to the elevation of the river channel) (Knox 2006). This has resulted in the filling and loss of many sloughs and a decrease in the amount of groundwater the remaining sloughs receive, to the detriment of the Starhead Topminnow populations that occupy them. These sloughs are also increasingly isolated from the river channel, to which they may be only connected during floods, and thus are more vulnerable to drying. This process is illustrated by our findings from the Lower Sugar River in Avon Bottoms near the Illinois border. Here, Starhead Topminnows had not been seen for many years and were thought eliminated (Lyons et al. 2000) when we conducted a status survey during 2009–2010. We found the Sugar River channel to have steep eroding banks, and many sloughs shown on earlier maps had either disappeared or were much smaller in size and no longer connected to the channel except during high flows. During the early part of our surveys, Starhead Topminnows were nowhere to be found. However, by late August 2010, several floods (Figure 9) had reconnected and rewatered some of the remaining sloughs, and we found a total of 31 Starhead Topminnows in several surveys. Apparently a small, remnant population had persisted and was able to repopulate portions of the floodplain when hydrological conditions were favorable. The Starhead Topminnow is a short-lived but rapidly reproducing species, maturing after one year and rarely living more than three growing seasons (Becker 1983, Taylor and Burr 1997), and it is adapted to exploiting and rapidly expanding into new suitable habitats as they become available.

In September 2010, we visited a recently constructed wildlife “scrape” (shallow artificial pond created for duck habitat) (Figure 10) on the floodplain near the Lower Sugar River sloughs where we had found the Starhead Topminnows. It was normally isolated from the channel, but the flooding had temporarily connected it for several weeks. This scrape now had hundreds of mostly young-of-the-year Starhead Topminnows. By 2011, the floods had ceased and the connection between the scrape and the channel was broken. We found just a single adult Starhead Topminnow in our surveys there that year. The next year, 2012, a drought occurred, the scrape dried up, and any remaining Starhead Topminnows were eliminated. The scrape had no groundwater to keep it wet during dry weather. Shallow sloughs perched above the water table appear to be common features of accreted floodplains. Although they may serve as temporary Starhead Topminnow habitat during wet periods, they ultimately cannot maintain the species in the face of drought.

In the Fox River drainage, an additional threat to Starhead Topminnow populations is urban sprawl. The Fox River flows just to the west of the Milwaukee, Racine, and Kenosha metropolitan areas, and residential and commercial development in the drainage is widespread and increasing. Watershed urbanization in this area has led to more variable flow conditions (i.e., greater and more frequent floods coupled with diminished low flows that last longer), decreased water quality, and loss of natural shoreline and channel habitats (Wang et al. 2001), all of which may harm Starhead Topminnow populations. Residential development has been particularly acute along the shorelines of the glacial lakes in the drainage (Marshall and Lyons 2008), and often includes loss of habitat caused by mechanical harvesting or poisoning of the shoreline aquatic plants favored by Starhead Topminnows.

Unfortunately, habitat loss is not the only threat facing Starhead Topminnows in Wisconsin. During the early 2000s, the non-native Western Mosquitofish *Gambusia affinis* became established in two areas, the Mississippi River in Pool 11 about 50 kilometers downstream of the Lower Wisconsin River, and a slough on the Sugar River about 20 kilometers upstream of the small Starhead Topminnow population known there. In neither area are there any barri-

Figure 10. A wildlife scrape (constructed shallow pond for duck production) along the Lower Sugar River in Avon Bottoms near the Illinois border in 2010 (left), after four floods had connected it with the river channel, and in 2012 (right), when it was completely dry during a drought. (Photo by Dave Marshall)

ers that would prevent Western Mosquitofish from reaching the Starhead Topminnow populations. Experiments have shown that Western Mosquitofish are more aggressive and efficient feeders than Starhead Topminnows, and that Starhead Topminnow growth and survival declines when western mosquitofish are present (Sutton et al. 2009). Expansion of the Western Mosquitofish in Wisconsin is likely to be bad news for Starhead Topminnows.

THE FUTURE

The future of Starhead Topminnows in Wisconsin is uncertain. Populations in the Lower Black River, Lower Sugar River, and Camp Lake are small and isolated, and as such they are vulnerable to extreme weather events, accidents (e.g., chemical spills), and invasive species. With climate change, extreme weather is becoming more common, increasing the risks for these three areas. The populations in the Mukwonago River system and the Lower Wisconsin River are more widespread, numerous, and interconnected and thus probably more secure. But urban sprawl is an ongoing and persistent threat in the Mukwonago; floodplain terrace farming and groundwater pollution have already harmed Starhead Topminnows in the Lower Wisconsin River, and Western Mosquitofish invasion is a looming problem. None of these threats are easily eliminated. Urban sprawl is a seemingly inexorable force, although good progress has been made by the Nature Conservancy and the WDNR in protecting riparian and watershed natural lands in Mukwonago River drainage. Along the Lower Wisconsin River, groundwater pollution is a difficult issue. Nutrients entering the groundwater bypass buffer strips established to filter surface runoff along the river corridor, and groundwater nutrient concentrations can be improved only if fertilizer applications to the floodplain terrace fields are reduced. However, lower applications could drop agricultural yield and make intensive cultivation uneconomical. Decreases in nutrient applications or reductions in floodplain farming are unlikely without new stricter regulations, generous incentives, or both. Unfortunately, the Lower Wisconsin River may no longer meet the criteria for Becker's (1983) proposed topminnow sanctuary.

These realities led us in 2017 to develop a project to re-introduce the Starhead Topminnow in appropriate habitats along the Wisconsin River above the Prairie du Sac Dam using individuals from the Lower Wisconsin River as broodstock. We would collect a diverse assortment of wild Starhead Topminnows from Lower Wisconsin River sloughs, breed these fish and raise their offspring in an off-site pond, certify that the offspring were in good health and stock them at multiple locations above the dam, and monitor those locations to determine if the species became established. This project would have two benefits, first preserving the genetic stock of the Lower Wisconsin River in a more secure area, and second, increasing the number of Starhead Topminnow populations and individuals in Wisconsin. The re-introduction effort began in 2018 and will conclude in 2021. In our next article, we will describe how the project has played out and whether we have been successful in re-establishing the Starhead Topminnow above the Prairie du Sac Dam.

ACKNOWLEDGMENTS

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