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FEATURE

Restored oxbows reduce nutrient runoff and improve fish habitat

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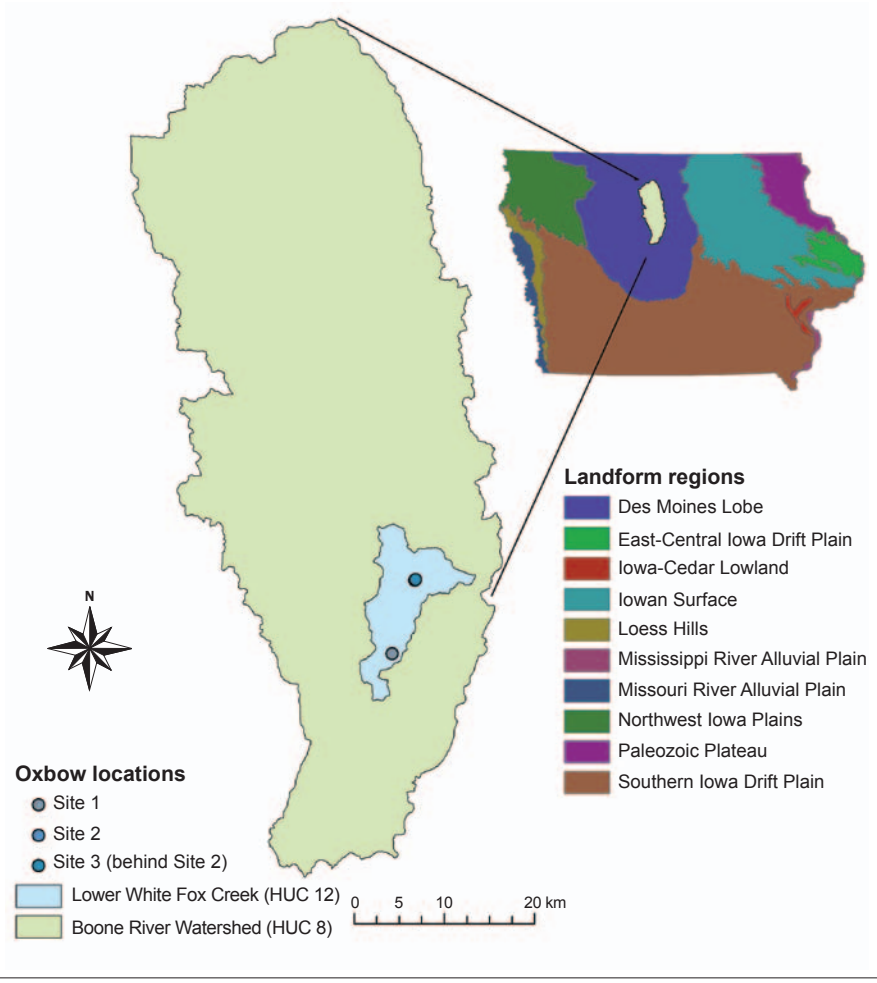
An oxbow is a remnant meander of a river or stream that has been cut off from present flow as the stream channel has migrated within its floodplain. The remaining depression is often connected to the water table, leaving pools of standing water throughout the year. Regular flooding and land use practices cause sediment and organic material to be deposited in the depression over time. The deposited material reduces the depth of the historic oxbow, limiting its potential for flood storage, nutrient cycling, and off-channel fish habitat.

In recognition of the important ecosystem services that they provide, the US Fish and Wildlife Service (USFWS) has been restoring oxbows in the Raccoon River Watershed in Iowa since 2002 (Betts 2014). The USFWS, the Nature Conservancy (TNC), Iowa Department of Natural Resources (IDNR), Iowa Soybean Association (ISA), Sand County Foundation (SCF), USDA Natural Resources Conservation Service (NRCS), and other partners have contributed to additional oxbow restorations as an innovative fish habitat improvement and tile line nitrate (NO_3) treatment practice. Partners have worked with area producers through a voluntary conservation program to restore a series of oxbows that collect water from tile lines. The practice is intriguing to landowners since water quality and wildlife responses have been notable and potential sites are typically found on marginal land unsuitable for production.

Recently, partners from these initiatives in Iowa and two neighboring states have formed the Fishers and Farmers Partnership (FFP). It is one of 19 such partnerships operating under the umbrella of the National Fish Habitat Partnership. The FFP efforts add value to farms while restoring aquatic habitat onsite and downstream on the Mississippi River. Projects are led by landowner committees, with flexible cost-share funding and technical support from conservation partners. The Partnership is restoring habitat in three designated areas: Boone River Watershed in Iowa (BRW), Seven Mile Creek in Minnesota, and Bourbeuse/Meramec River System in Missouri. Habitat improvements in the BRW have focused on the elimination of fish barriers and the restoration of disconnected oxbows. FFP believes oxbow restorations will improve water quality and provide crucial habitat for fishes, especially the endangered Topeka shiner (*Notropis topeka*) (Bakevich et al. 2013).

The potential of oxbow restorations to reduce nitrogen (N) loads to the Greater Mississippi Basin prompted SCF's interest in these projects. This paper focuses on three sites (sites 1 to 3) funded for this purpose by SCF and restored by ISA's Environmental Programs and Services in partnership with TNC. The paper describes how sites 1 to 3 were selected and restored, and it presents preliminary results from water quality monitoring and fish survey data.

Figure 1
Location of restored oxbows paired with tile lines.



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BACKGROUND ON THE BOONE RIVER WATERSHED

The BRW is located in the prairie pothole region of the Des Moines Lobe and covers parts of six counties, with most of the area located in Hamilton, Wright, and Hancock counties (figure 1). The BRW is the largest tributary of the Des Moines River, the source of drinking water for the city of Des Moines to the south. The watershed has a drainage area of 2,352 km^2 (908 mi^2). There are 1,223 km (760 mi) of streams that support a diversity of fishes and other wildlife species, including the Topeka shiner. About 185 km (115 mi) of stream are designated as a Protected Water Area by the IDNR, and this is primarily in the lower reaches (IDNR 2015).

Threats to water quality in the BRW include nutrient pollution and sediment loading (USDA NRCS 2008). About 99% of land in the watershed is privately held and 90% is in corn (*Zea mays* L.) and soybean (*Glycine max* L.) production. This watershed is among the healthiest in Iowa, but landscape alterations are changing water quality, stream flow, and physical habitat in ways that impact the watershed's plant and animal communities. The Des Moines River is considered impaired for NO_3-N (IDNR 2013). The BRW was designated as a Mississippi River Basin Initiative watershed in 2010. These watersheds have been targeted to implement voluntary conservation practices that improve water quality, restore wetlands, enhance wildlife habitat, and sustain agricultural profitability in the Mississippi River Basin (Enloe et al. 2014).

PRERESTORATION WATER QUALITY DATA

Extensive preproject water quality data exist for White Fox Creek, a tributary to the Boone River. These data were the result of monitoring conducted by ISA and funded by Agriculture's Clean Water Alliance. Two sites are monitored regularly: 42°37'47.6394" N, 94°44'45.9594" W (BR12) and 42°30'27.7194" N, 93°48'23.3994" W (BR08). From 2007 through the end of 2011 when oxbow restorations began, 75 samples from each stream site were collected. These samples were analyzed for NO_3-N, nitrite-N (NO_2-N), chloride (Cl), sulfate (SO_4), and orthophosphate using US Environmental Protection Agency method 300.0 (ion chromatography). Samples collected from 2007 to 2010 were analyzed at the Des Moines Water Works (DMWW) laboratory. Samples collected from 2011 to 2013 were analyzed at the ISA laboratory. Both the DMWW and ISA Laboratories are certified for NO_3-N analysis by the State of Iowa. Quality control procedures at both labs include blanks, fortified samples (spikes), replicates, and known concentration samples, all analyzed with each batch.

Like many streams in Iowa, White Fox Creek has elevated NO_3-N levels. From 2007 to 2013, 101 of the 191 water samples tested (53%) exceeded the drinking water standard of 10 mg L^{-1} (10 ppm). Thus, any habitat project that could sequester or remove N from the stream network would benefit downstream users of the water resource. Since the restored oxbows at sites 1 to 3 were designed to receive tile effluent water, these tiles were monitored for NO_3-N and orthophosphate in the year prior to construction.

Table 1

Details of excavation extent and cost.

Site	Area (ha)	Depth of excavation (m)	Material removed (m^3)	Cost (US$)
1	0.17	1.2	2,072	9,486
2	0.11	1.2	1,382	6,324
3	0.16	1.2	1,973	9,035

RESTORATION SITING AND CONSTRUCTION

The IDNR identified the oxbow and barrier locations in the BRW with Light Detection and Ranging (LiDAR). TNC examined aerial photography to determine potential locations for oxbow restoration in the BRW. ISA then organized a Rapid Assessment of Stream Conditions Along Length (RASCAL) as part of a watershed planning effort for White Fox Creek. Part of the RASCAL included georeferencing tile outlets. The resulting shapefile was overlayed with LiDAR to target remnant oxbows for potential denitrification.

Sites 1 through 3 were identified by NRCS as properties with possible landowner collaborators. Except for a small parcel in the floodplain of White Fox Creek, most of this land was committed to corn and soybean production. TNC determined that remnant oxbows at the sites had the characteristics needed for successful restoration. IDNR coordinated the process for State Historical Preservation Officer review and concluded that the oxbow sites had low potential to contain relics.

In December 2012, mild weather enabled contractors to complete sediment removal efforts. An average of 1.2 m (4 ft) of sediment was removed from each site such that the bottom elevation matched that of the streambed (figure 2). Spoil material from the excavation was deposited in a nearby field. Table 1 lists the excavation details for each of the sites.

It is expected that high flow events from White Fox Creek will connect the stream to the oxbow about once every two to three years. This did in fact happen in the spring of 2013, when floodwaters reached all three oxbows.

With sediment removed, groundwater was once again able to infiltrate through the native sand and gravel deposited during the last glacial period. The oxbow immediately filled with water, notwithstanding the dry conditions that existed at the time. The banks of the restored oxbows were reseeded with native plant species in the spring of 2013. The total cost for each restoration was less than US$10,000, quite low for stream habitat projects.

POSTRESTORATION RESPONSE

Water Quality. Elevated nutrient levels in the BRW are a continuing problem that vexes researches and farmers alike. One objective of this project is to determine the nutrient abatement potential of restored oxbows. To assess this, partners TNC and ISA developed a biweekly sampling schedule during the open water season for the restored oxbows and the tiles emptying into them.

These water quality data address the question of whether or not restored

Figure 2

White Fox Creek site 1 oxbow restoration (a) in November of 2012 prior to restoration, (b) during restoration in December of 2012, (c) in January of 2013 (photo by Bruce Voigts), and (d) in April of 2013. Tree is highlighted for reference.

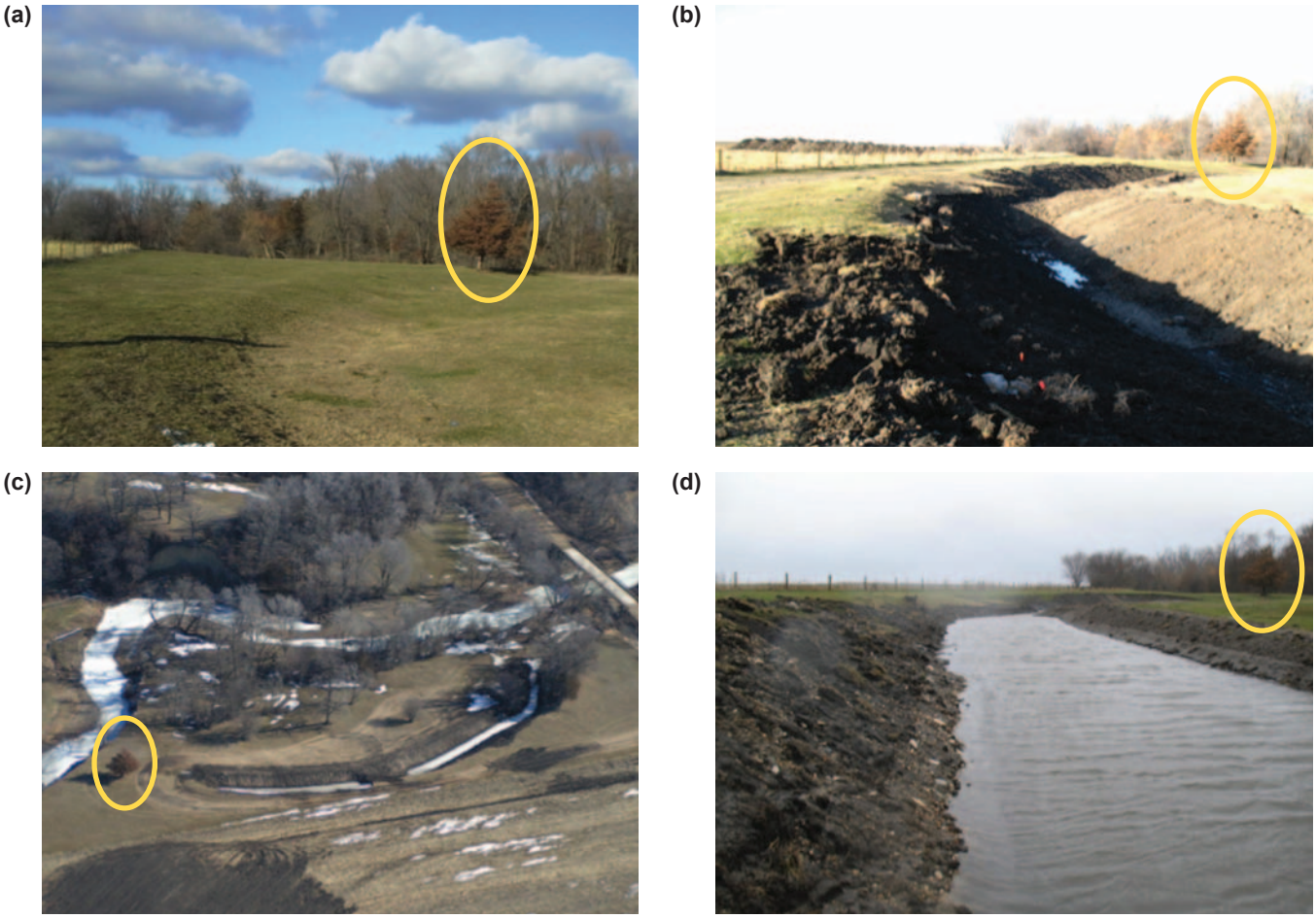

Table 2

2014 average concentration and percentage change of nitrate-nitrogen (NO_3-N) in oxbows 1 through 3 as compared to inlet tile water. The site 1 inlet was sampled 16 times; all other sites were sampled 14 times.

	NO_3-N (mg L^{-1})		
Site	Inlet	Oxbow	Change (%)
1	16.3	6.2	-62
2	8.8	4.8	-45
3	8.8	3.4	-61

oxbows can provide edge-of-field NO_3-N reduction treatment. Table 2 illustrates concentration data for NO_3-N for each of the three sites. Nitrate concentration reductions in 2014 averaged 56% as a result of biological processes. The incoming N is either denitrified in anaerobic sediments of the oxbow or assimilated into plant and animal matter. It is difficult to fully quantify N load reductions in the oxbow, however, because groundwater dilution is also a candidate for reduced concentrations. This will be addressed in 2015 with additional research.

Clearly these restored oxbows can serve a dual role of improving downstream water quality by removing tile water contaminants from the artificially drained landscape of the BRW while also providing critical habitat for fishes, birds, amphibians, and reptiles.

Fish Surveys. As mentioned earlier, White Fox Creek flooded in May and June of 2013. This enabled resident fish to populate the oxbows. Following FFP protocols, postrestoration monitoring was conducted by Iowa DNR Fisheries staff on April 10, 2014. Although no Topeka shiners were captured during the postrestoration survey, the results are encouraging. Fourteen native species colonized the oxbows and were able to survive one of the coldest winters in recent years (table 3). If Topeka shiners exist in White Fox Creek, then they should eventually colonize these oxbows.

CONCLUSION

This project demonstrates that oxbow restorations are a good strategy for water quality improvement of adjacent streams. Oxbows have the potential to quench much of the incoming N, a major water quality problem for the BRW and Mississippi River Basin. Future restorations should consider directing tile effluents into oxbows to reduce nutrient

Table 3

Results of postrestoration fish surveys conducted by Iowa Department of Natural Resources at sites 1 through 3 on April 10, 2014. The previous winter was among the coldest in recent years and most likely reduced overwintering success; there were signs of winterkill at site 2, mostly bigmouth buffalo.

	Number of individuals		
Species	Site 1	Site 2	Site 3
Bigmouth buffalo	—	74	—
Bigmouth shiner	57	36	—
Black bullhead	—	11	11
Bluntnose minnow	1	1	—
Brassy minnow	—	77	1
Common carp	—	1	—
Common shiner	51	35	1
Creek chub	4	—	—
Golden shiner	—	2	25
Green sunfish	—	4	—
Sand shiner	8	—	—
Spotfin shiner	4	1	—
Stoneroller	5	4	—
White sucker	—	—	5

export to streams and ensure year-round water for the oxbow.

Although Topeka shiners have not yet been captured in these oxbows, it seems very likely that they will eventually colonize the new habitat. The species has been observed in other tributaries of the BRW, and since these are similar to White Fox Creek in terms of water quality, slope, land use, and other variables, it is reasonable to expect that they will eventually appear in the oxbows and adjacent stream. Deliberate introduction remains an option if colonization does not occur within the next five years.

There are between 30 and 100 high quality oxbow remnants in the BRW. Clustering restorations within one watershed presents the opportunity to implement a truly landscape-scale practice that benefits water quality and habitat and helps restore some of the natural hydrology that was lost when the region was converted to row crop production.

We believe this strategy is one that can be implemented successfully in other farmed landscapes. Since oxbows are in floodplains, it is unlikely that a landowner will want to cultivate nearby land. The cost is very modest for a habitat restoration, and landowners see water quality and recreational value for the project. Given these advantages, partners will continue to monitor restoration sites with the intent of gathering sufficient data for a peer-reviewed publication.

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