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Comparison of Sampling Methods for Small Oxbow wetland Fish Communities

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ABSTRACT

The value of wetland ecosystems is becoming increasingly recognized, promoting actions needed to preserve and restore them. Post-restoration monitoring is necessary to analyze restoration success or failure, thereby informing subsequent management decisions. Standardized monitoring protocols enable comparison of responses to restoration actions. Within the Midwestern United States, restoration of oxbow wetlands has become the focus of targeted restoration. Management objectives include recovery of biodiversity and sensitive species, and enhanced ecosystem services. The fish communities of oxbows have been the subject of many monitoring studies as endangered Topeka Shiner (*Notropis topeka*) use these habitats for spawning. However, an optimal method for monitoring Topeka Shiner and other fishes in oxbows has not been described, thereby limiting our capacity to effectively manage these ecosystems. With a primary objective of identifying a standardized protocol for sampling fish in oxbow wetlands, we compared efficacy of four sampling methodologies (backpack electrofishing, fyke netting, minnow trapping, and seining) for fish community data collection. Seining and fyke netting were determined to be the most effective methods for sampling oxbow fish communities. Although seining and fyke netting produced similar taxonomic diversity and

abundance values, qualitative analysis revealed that seining caused greater habitat disturbance and stress to fish. Therefore, consideration must be given to how species present within the wetland could be impacted by sampling disturbance when choosing between seining and fyke netting.

Keywords: Oxbow, endangered, restoration, monitoring, sampling, efficacy

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INTRODUCTION

Throughout the world, increasing emphasis is being placed on restoration of degraded aquatic habitats and their ecosystem services (Palmer et al. 2014). Wetlands are among the most impacted aquatic ecosystems, with declines in both areal coverage and habitat quality occurring as the global human population increases (Davidson 2014). Fortunately, recognition of the value of wetlands has generated interest in preserving and restoring them. Wetland restoration activities range in scope and complexity from watershed-scale undertakings to targeted fine-scale enhancements of habitats. As these activities have expanded, so has realization of the value of monitoring sites post-restoration to assess management successes or failures (Rubin et al. 2017; Roni et al. 2018). Standardized monitoring protocols are imperative for comparing success of

different restoration strategies and responses of different types of wetlands to these management actions. (Roni et al. 2018).

Within the Midwestern United States, oxbow wetlands (hereafter oxbows) have recently become the focus of targeted restoration efforts. Oxbows are floodplain habitats consisting of river meanders that have been disconnected from the main channel through natural erosional processes, creating an off-channel lentic habitat (Ward et al. 2002; Charlton 2008). As prairies, forests, and other forms of natural land cover in the region were replaced by cropland and pasture, streams were channelized, eliminating many oxbows (Dodds et al. 2004; Costigan and Daniels 2012). As oxbows declined in number, their ecosystem services were also lost. In floodplain habitats, oxbows are especially valuable because they retain water, thereby reducing downstream flooding (Schilling 2017). By capturing and sequestering nutrients, oxbows can contribute to improved stream water quality (Schilling 2017; Schilling 2018). Additionally, oxbows contribute to increased biodiversity by providing essential wetland habitat for many species (Miranda 2005; Rodrigues 2015; Jones et al. 2015; Schilling et al. 2018).

Within the states of Iowa, Minnesota, and South Dakota, restoration of oxbows has increased substantially over the last twenty years. In Iowa alone, restoration of oxbows has increased from 1.2 restorations per year from 2001-2005 to 12.8 restorations per year from 2016-2020 (Fig. 1). Iowa oxbows are being restored because of ecosystem services described above, and because they appear to provide critically important habitat for the Topeka Shiner *Notropis topeka*, a species of fish that is listed by the United States Fish and Wildlife Service as an endangered species (Tabor 1998; Schilling et al. 2017; Schilling et al. 2018; Simpson et al. 2019).

Accelerating oxbow restoration has led to increased monitoring of these ecosystems by The Nature Conservancy, the United States Fish and Wildlife Service, the United States Geological Survey and other entities. Monitoring projects are conducted in part to determine success or failure of restoring oxbow ecosystem services. Monitoring typically involves collecting habitat data (depth, width, length, bank angles, substrate, canopy cover, etc.) and conducting plant and invertebrate community surveys. Given that oxbows are critical habitat for Topeka Shiner, research has also focused on fish communities of restored and unrestored oxbows (Bakevich et al. 2013; Fischer et al. 2018; Simpson et al. 2019).

While many studies have examined oxbow fish communities, a standard sampling protocol does not exist for these habitats, and some methods are likely more effective than others (Bakevich et al. 2013). Sampling methodologies employed in previous fish community surveys include seining with a bag seine of variable sizes and numbers of seine passes (Bakevich et al. 2013), blocking the oxbow into four sections and sampling three while leaving one section as an undisturbed fish refuge (Fisher et al. 2018), and “scoop” seining (1.2 x 1.2 m seine with 6.4 mm mesh; Dahle 2001). Because the Topeka Shiner is a rarely encountered species with a restricted geographic distribution and specific habitat requirements, it is important to identify the most effective fish community survey method for oxbows. An ideal method would produce consistently accurate population data while minimizing stress to fish. Development of a standard protocol based on this sampling method will enable sampling without causing significant fish mortality, and direct comparison of results from fish surveys conducted in different oxbows.

In this study, we quantitatively compared values for three fish community metrics (total CPUE, species richness, and 10th-90th quantile length ranges of fish collected) that were obtained using four sampling methods. Additionally, we qualitatively compared these methods in terms

of ease of use, stress to fish, habitat disturbance, ability to sample in dense vegetation, and ability to sample in deep water. Objectives were to identify best practices for describing fish community structure in oxbows, and propose a standard protocol for conducting fish community surveys.

METHODS

Study sites consisted of 12 recently restored oxbows located in central Iowa (10 within the Boone River basin, two within the North Raccoon River basin; Fig. 2). Oxbow length, width and depth ranged from 23 m to 139 m, 4.8 m to 20.4 m, and 0.56 m to 0.98 m, respectively, with average values of 77.4 m, 10.0 m, and 0.69 m (Average $\pm$ SD; Table 1). Fish communities at all oxbows were surveyed over a four-week period using four sampling methodologies (backpack electrofishing, fyke netting, minnow trapping, seining). Seining is a frequently-used fish sampling methodology in oxbows (Simpson et al. 2019; Bakevich et al. 2013). Fyke netting and minnow trapping are commonly used to sample fish in a variety of depressional wetlands (Bryant 2001; Kneib and Craig 2001; Ruetz et al. 2007; Maurer et al. 2014). Although infrequently used in wetlands, we included backpack electrofishing given the widespread use of this sampling method in fisheries field research.

Oxbow sampling sequence and order of methodology implementation were randomized (using a random number generator) to control for time effects on results. For each sampling method, all fish collected were identified to species and total numbers were counted. Total lengths of the first 50 recovered individuals for each species were measured. All fishes were subsequently released into the oxbow where they were captured.

Sampling Methods

Backpack electrofishing was performed by a single pass with a backpack unit (Smith-Root LR-20B Backpack Electrofisher) across all wadeable habitat by walking along the entire shoreline perimeter. One investigator carried the backpack, while one netter on each side

collected fish. Electrofishing settings were determined based on conductivity of water in the oxbow (10-500 $\mu\text{s}/\text{cm}$, 200-300 volts; 500-800 $\mu\text{s}/\text{cm}$, 150-200 volts; 800-1000 $\mu\text{s}/\text{cm}$, 120-180 volts; >1000 $\mu\text{s}/\text{cm}$, 100-150 volts).

Fyke netting consisted of placing three, un-baited, mini-fyke nets (4.0 m lead, 0.6 cm mesh, largest hoop opening = 0.6 m $\times$ 1.2 m) in each oxbow. Nets were placed perpendicular to the shoreline within the open water zone at points spaced evenly along the length of the oxbow. Fyke nets were deployed for 24 h, and then retrieved.

Minnow trapping consisted of placing four, un-baited, minnow traps (2.5 cm opening, 0.6 cm mesh, 0.4 m long $\times$ 0.2 m diameter) at points evenly spaced along the length of the oxbow and at variable depths (0.3 m to 1.1 m) with two traps on each bank. Minnow traps were retrieved after 24 h of deployment.

Seining was conducted using a single pass of a bag seine (10.7 m $\times$ 1.8 m, 0.6 cm mesh or 16.8 m $\times$ 1.8 m, 0.6 cm mesh depending on oxbow width) along the entire length of the oxbow. For oxbows < 16 m in average width, the 10.7 m wide seine was used. For oxbows >16 m in average width, the 16.8 m wide seine was used. Simpson et al. (2019) found that a single seine pass (rather than multiple passes) was sufficient for surveying the fish community of an oxbow. A single seine pass is more desirable compared to multiple seine passes given the reduced effort, and decreased fish stress and mortality (Bakevich et al. 2013).

Fish Community Metrics and Data Analysis

To investigate effects of sampling method, we focused our quantitative analyses on three fish community metrics. Total catch per unit effort (CPUE) was measured as the number of fish collected per 100 m² sampled during the sampling event as is consistent with other studies analyzing oxbow fish communities (Bakevich et al. 2013; Simpson et al. 2019). Species richness

was quantified as the number of species collected from one oxbow during one sampling event. The 10-90th quantile range for lengths was calculated for each sampling event and these values were used for comparison. Values for species richness and total CPUE were log transformed prior to analysis. Qualitative analyses focused on five metrics (ease of use, perceived stress to fish, perceived stress to habitat, ability to sample in dense vegetation, ability to sample deep water).

All analyses and figures were conducted and created using program R (version 3.6.3; R Core Team 2020) and packages **emmeans** (Lenth 2020), **ggribdges** (Wilke 2020), **vegan** (Oksanen et al. 2019), **ggplot2** (Wickham 2016), **lme4** (Bates et al. 2015), and **plyr** (Wickham 2011). Fixed effects linear regression models were fit for each quantitative metric of interest (species richness, total CPUE, 10th-90th quantile length range) with sampling method, oxbow, and week included as additive predictors. A type III ANOVA was used to test for effects of sampling method on each fish community metric. The emmeans function was used to examine contrasts between sampling methods for each metric with results averaged over the levels of oxbow and week and P values adjusted using the Tukey method for comparing a family of four estimates. The critical value for statistically significant differences was $P \leq 0.05$.

RESULTS

In total, 48 sampling events occurred (12 oxbows x 4 sampling events at each oxbow), resulting in collection of 32862 individual fish and 26 species (Table 2). Within the sampling period, a fish-kill occurred at one oxbow, likely due to low dissolved oxygen levels as a result of decaying organic matter. Therefore, data from that oxbow were not included in analysis, resulting in 11 oxbows and 44 sampling events included in statistical analysis.

Fathead Minnow *Pimephales promelas* was collected from all oxbows and represented 73 % of the fish collected during sampling. Golden Shiner *Notemigonus crysoleucas* was the second

most common fish sampled, representing nearly 9 % of the total catch, although this species was collected from only 5 of the 11 oxbows. Seven of the 26 species collected represented over 97% of the total fish collected (Table 2). Five species were collected from only one oxbow while two species were collected at each oxbow (Table 2). Two Topeka Shiner were collected during sampling.

Sampling method had a significant effect on total CPUE ($P < 0.001$), species richness ($P < 0.001$), and fish lengths ($P < 0.002$; Tables 3-6). Total CPUE was significantly greater for fyke netting and seining than backpack electrofishing and minnow trapping (Table 4; $P < 0.0001$). Species richness was significantly greater for fyke netting, seining and backpack electrofishing than minnow trapping (Table 5; $P \leq 0.009$). The range of fish lengths collected by seining and fyke netting were significantly larger than the range of fish lengths collected by minnow trapping (Table 6; $P < 0.002$). The range of fish lengths collected by backpack electrofishing was not significantly different from the range collected by the other three methods.

Backpack Electrofishing

Total CPUE values obtained via backpack electrofishing were low compared to other methods, indicating that this method is ineffective for sampling oxbow fish communities (Table 4). Species richness values produced by backpack electrofishing (range = 1—11 species per oxbow based on 11 sampling events) were lower than fyke netting (2—16 species) and seining (2—16 species), indicating that backpack electrofishing fails to detect many species occupying an oxbow (Table 3). Backpack electrofishing was successful in collecting the 13 most common of the 26 total species collected (Table 2). However, seven of the 13 least common species were absent from collections made via backpack electrofishing. Length frequency distribution data

186 indicate that backpack electrofishing disproportionally sampled smaller fish than other methods
187 we employed (Fig. 3).

190 **Fyke Netting**

191 Total CPUE values from fyke netting were comparatively high, indicating that this
192 technique is effective in capturing fishes occupying the oxbow (Table 4). Furthermore, fyke
193 netting resulted in the collection of 24 of the 26 fish species recorded during the study, missing
194 only Rock Bass (representing the lowest proportion of total catch, collected at one oxbow) and
195 Yellow Perch (representing the fourth lowest proportion of total catch, collected at one oxbow)
196 (Table 2). Additionally, a single Topeka Shiner was collected via fyke netting at one oxbow.
197 These findings, in combination with the high species richness values, indicate that fyke netting is
198 effective at detecting rarer species. Length frequency distribution results from fyke netting
199 indicate that this method effectively samples the entire range of fish sizes present in the oxbow
200 compared to other methods used (Fig. 3).

201 **Minnow Trapping**

202 Total CPUE values from minnow trapping were the lowest of the four methods tested
203 (Table 4). Minnow trapping resulted in collection of seven species in total, but no more than
204 three species were collected during any one sampling event (Table 3). Lengths of fish collected
205 via minnow trapping were significantly greater than those collected via backpack electrofishing,
206 and fyke netting but were similar to those collected via seining (Table 5). Minnow trapping
207 appears to be more size-selective for fish in the length range of 40 to 90 mm, in comparison to
208 other sampling methods (Fig. 3).

Seining

Total CPUE values indicate that sampling efficiency via seining is high. Seining resulted in collection of 24 of the 26 species found during this study, missing only Black Crappie (tenth lowest proportion of total catch, collected at one oxbow) and Carmine Shiner (third lowest proportion of total catch, collected at one oxbow; Table 2). The range of species richness values generated by seining (2-16 species) was identical to that of fyke netting (Table 3). Furthermore, a single Topeka Shiner was collected via seining at one oxbow. As was true for fyke netting, it appears that seining effectively samples rarer species of fish. Seining does not appear to be size-selective (Fig. 3).

DISCUSSION

Comparison Of Sampling Methods For Fish Community Sampling

Our findings indicate that seining and fyke netting are the most effective sampling methodologies evaluated in this study. These conclusions are based on high total CPUE and species richness values, unbiased sampling of various size classes, ability to sample deep-water habitat, and ability to detect presence of Topeka Shiner. These two methods performed more effectively in comparison to backpack electrofishing and minnow trapping. While fyke netting and seining both appear to effectively sample oxbow fish communities, there are differences in ease of implementation of each gear type as well as the level of habitat disturbance generated.

Backpack Electrofishing

Backpack electrofishing was a difficult technique to use in oxbows. First and foremost, turbidity is typically high within oxbows and sediment is easily suspended. Given that efficacy of backpack electrofishing relies heavily on the netter's ability to see stunned fish (Zalewski and Cowx 1990), relying on this sampling method in turbid systems is not recommended. Furthermore, the sampled oxbows frequently contained areas in which water depth was > 1m. To

maintain the backpack electrofishing unit's functionality by avoiding the submersion of the circuitry and power source, much deep-water habitat was unsampled. Presence of dense submerged plants also created difficulty because fish stunned by the electrical currents became ensnared in vegetation and did not surface.

Backpack electrofishing can also be stressful to fish (Snyder 2003; Awata et al. 2013). Handling stress may be high as this method does not lend itself well to holding fish for data collection after sampling. Fish are transferred from the collection net to a larger holding container within the oxbow, which at times involves a significant amount of handling. In terms of stress to the habitat, backpack electrofishing in our study involved three individuals walking through the entire wadeable portion of the oxbow. This leads to heavy disturbance of sediment, increased turbidity, and displacement of vegetation.

Fyke Netting

Fyke netting had multiple drawbacks (amount and weight of gear, time requirements) and benefits (low stress to fish, ability to sample in deeper water and dense vegetation). The amount and weight of gear needed for fyke netting created difficulty when hauling gear to study sites (in our case, a distance up to 1 km). Fyke netting is time-consuming as nets must be deployed for 24 h, which necessitates site visits on successive days. However, fyke nets are effective at sampling fish communities in densely vegetated habitats (Maurer et al., 2014). Furthermore, habitat disruption by fyke netting is not as extensive as that caused by more active forms of sampling, including backpack electrofishing and seining. For fyke netting, habitat disruption within an oxbow is generally confined to placement locations of fyke nets, and does not result in widespread disturbance of vegetation and benthic substrate.

Handling stress from fyke netting is likely similar to that caused by minnow trapping but lower than seining and backpack electrofishing. In fyke netting, fish can be quickly transferred from the net to a holding container and then counted and released immediately. However, fish are restrained within the net for up to 24 h, depending on when they enter the net. This restraint may disrupt normal behavioral patterns and expose fish to increased predation risk if the net is occupied by piscivores such as Green Sunfish, Largemouth Bass, or turtles.

Minnow Trapping

Minnow trapping is easy to implement as a sampling practice given the small size and low cost of traps and the ease with which they can be placed into the oxbow. However, minnow trapping is likely an ineffective sampling methodology for oxbows with significant aquatic vegetation. Aquatic macrophytes along the bottoms of an oxbow may inhibit effectiveness of minnow traps because entry funnels may become clogged or covered with vegetation. Also, given the small size of the funnel leading to the trap entrance, it is likely that each trap is sampling only a small proportion of the total habitat present at an oxbow in comparison to backpack electrofishing, fyke netting, and seining.

Minnow trapping causes minimal disturbance to oxbow habitat. Minnow traps can be deployed from the shoreline, without an investigator having to enter aquatic habitat. While habitat disturbance may be limited, stress to fish collected via minnow trapping may occur. Similar to fyke netting, fish confined within a minnow trap may experience disruption to normal behavioral processes, such as feeding, for up to 24 h. However, unlike fyke netting, given the size selectiveness of minnow trapping, fish in traps are unlikely to experience increased predation risk because larger piscivores are unable to enter traps.

Seining

Seining can be effective for sampling deep water up to the height of the seine (1.8 m), as investigators pulling the seine may remain along the shallow shoreline of the oxbow during sampling. Fisher et al. (2018) documented detection probabilities ranging from 40% to over 90% for fish species in similar oxbows using similar seining techniques. However, for oxbows with dense aquatic vegetation or an abundance of woody debris/boulders, seining becomes arduous given the active nature of this method. For seining, fish are held entirely in the water until the moment each individual is counted, which may reduce handling stress. Also, the amount of time in which an individual fish is impacted is minimal compared to passive forms of sampling which may result in a fish being trapped for 24 h. However, when oxbows with significant aquatic vegetation are sampled, a risk exists for entanglement of fish within aquatic vegetation collected by the seine. Furthermore, seining can lead to habitat destruction within the oxbow. The lead line of a seine may disturb an oxbow's floor and up-root aquatic vegetation. If sampling occurs during the breeding season for nest building centrarchid sunfishes such as the Green Sunfish, and Bluegill (Topeka Shiner nest in association with each of these species; Pflieger 1997; Dahle 2001; Stark 2002; Witte 2009), this reproductive activity could be compromised.

Seining is one of the most common methods employed to sample fish in shallow-water habitats. It is the simplest method to employ in terms of gear needed. Furthermore, given the characteristic U-shaped depth profiles and narrow wetted widths of oxbows, a seine can be pulled through the entirety of the habitat, barring any large obstructions (submerged woody debris, boulders etc.). Also, seining allows for minimal handling because can be held in the water during processing and data collection.

Conclusions and Recommendations

Minnow trapping is ineffective in accurately describing the oxbow fish community. Other investigators determined that the catch of minnow traps is biased towards common species and is size-selective; our findings corroborate these studies (Layman and Smith 2001; Lapointe et al. 2006). Given the inability to effectively and unbiasedly sample the fish community, we do not recommend use of minnow trapping as a sampling method for oxbow fish communities. Furthermore, given the low CPUE values, ineffectiveness in sampling rarer species, difficulties in sampling deep and vegetated water, and high stress to habitat and fish, we do not recommend backpack electrofishing as a sampling methodology for oxbow fish communities. However, we do recommend both seining and fyke netting as best practices for oxbow fish community sampling. Quantitatively, fyke netting and seining appear to be comparable in fish community sampling efficacy. In our study, we found differences in lengths of fish collected, however, both sampling method appears to sample sizes classes without bias (Fig. 3).

When choosing between fyke netting and seining, consideration must be given to the amount of time needed to conduct sampling, habitat disturbance, habitat characteristics, accessibility of the oxbow, and time of year. For oxbows containing large quantities of aquatic vegetation or woody debris or boulders, fyke netting is the preferred sampling method. However, given the weight and difficulty in transporting fyke nets from a vehicle to the oxbow, seining may be preferable for oxbows that are not readily accessible by vehicle.

Recent Topeka Shiner surveys have involved sampling many oxbows over a short time period (Bakevich et al. 2013; Simpson et al. 2019). For studies constrained by a short timeline, seining may be more desirable as an oxbow can be visited once and sampled via seine within a few hours, while fyke netting requires two days and two visits to the oxbow to complete. However, if sampling is to occur during the breeding season of Topeka Shiner (or other species

of conservation concern depending upon the location of the study area), fyke netting is less likely to disturb habitat and may be preferable to seining.

Special Considerations for Topeka Shiner Sampling

Considering Topeka Shiner's imperiled status, it is crucial that a sampling method is employed that has a high likelihood of detecting this species when it is present. Although only two specimens were collected in our study, it appears that fyke netting and seining were the best methods to determine presence or absence of Topeka Shiner within an oxbow. In addition to sampling method effectiveness, consideration must be given to stress experienced by fish as surveys are conducted. These considerations are especially significant when handling species of greatest conservation concern. We recommend that during the breeding season for Topeka Shiner (mid-May to early August; Dahle, 2001; Witte, 2009), fyke nets or other passive sampling methods which are comparatively unlikely to disrupt spawning habitat should be used to minimize disturbance of reproduction. Outside of the potential breeding season, active sampling methods such as seining can be used to sample habitats where Topeka Shiner may be present. Fischer et al. (2018) documented detection probability of over 90% for Topeka Shiner in similar oxbows using similar seining techniques.

In summary, the monitoring of oxbows, both before and after restoration, is necessary to understand impacts of restoration on the fish community present within the oxbow. We must understand how restoration impacts the fish community to improve management practices that maximize benefits for target species (in this case, Topeka Shiner). We recommend that during the breeding season for Topeka Shiner (mid-May to early August), fyke netting should be used as the primary sampling methodology for oxbows that may hold the species. Outside of the

345 breeding season for Topeka Shiner, we recommend either seining or fyke netting as the primary
346 sampling methodology depending upon physical characteristics of the oxbow being sampled.

347

DECLARATIONS

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Conflicts of interest/Competing interests

The authors declare no conflicts of or competing interests.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability

The code used during the current study is available from the corresponding author on reasonable request.

Authors' Contributions

SS participated in the design and implementation of field data collection for this study. CL acquired the funding necessary to complete this study and provided edits and comments on manuscript drafts. TW provided guidance on study design as well as manuscript editing. AM provided guidance for statistical analysis. DO participated in the design and implementation of field data collection, analysis of data, and was the primary author of the manuscript. All authors read and approved the manuscript.

Ethics Approval

This study was approved by the Iowa State University Office of Research Ethics Institutional Animal Care and Use Committee

Consent to Participate

371 Not applicable

372

373 *Consent for Publication*

374 Not applicable

LITERATURE CITED

- AWATA S., T. TSURUTA, T. YADA, AND K. IGUCHI. 2013. Stress hormone response in ayu *Plecoglossus altivelis* in reaction to different catching methods: comparison between electrofishing and cast netting. *Fish. Sci.*, 79:157-162.
- BAKEVICH, B. D., C. L. PIERCE, AND M. C. QUIST. 2013. Habitat, fish species, and fish assemblage associations of the topeka shiner in west-central Iowa. *N. Am. J. Fish. Manag.*, 33:1258-1268.
- BRYANT, M. D. 2000. Estimating fish populations by removal methods with minnow traps in southeast Alaska streams. *N. Am. J. Fish. Manag.*, 20:923-930.
- CHARLTON, R. 2008. *Fundamentals of fluvial geomorphology*. Routledge, New York.
- COSTIGAN, K. H., AND M. D. DANIELS. 2012. Damming the prairie: human alteration of Great Plains river regimes. *J. Hydrol.*, 444:90-99.
- DAHLE, S. P. 2001. *Studies of Topeka Shiner (Notropis topeka) life history and distribution in Minnesota*. Master's thesis. University of Minnesota, Minneapolis, Minnesota.
- DAVIDSON, N. C. 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. *Mar. Freshwater Res.*, 65:934-941.
- DODDS, W. K., K. GIDO, M. R. WHILES, K. M. FRITZ, AND W. J. MATTHEWS. 2004. Life on the edge: the ecology of Great Plains prairie streams. *BioSci.*, 54:205-216.
- FISCHER, J. R., B. D. BAKEVICH, C. P. SHEA, C. L. PIERCE, AND M. C. QUIST. 2018. Floods, drying, habitat connectivity, and fish occupancy dynamics in restored and unrestored oxbows of west central Iowa, USA. *Aquat. Conserv.: Mar. Freshw. Ecosyst.*, 28:630-640.
- JONES, C. S., K. KULT, AND S. A. LAUBACH. 2015. Restored oxbows reduce nutrient runoff and improve fish habitat. *J. Soil and Water Conserv.*, 70:49-52.

- 399 KNEIB, R. T., AND A. H. CRAIG. 2001. Efficacy of minnow traps for sampling mummichogs
400 in tidal marshes. *Estuaries*, 24:884-893.
- 401 LAPOINTE, N. W., L. D. CORKUM, AND N. E. MANDRAK. 2006. A comparison of methods
402 for sampling fish diversity in shallow offshore waters of large rivers. *N. Am. J. Fish.*
403 *Manag.*, 26:503-513.
- 404 LAYMAN, C. A., AND D. E. SMITH. 2001. Sampling bias of minnow traps in shallow aquatic
405 habitats on the eastern shore of Virginia. *Wetl. Sci.*, 21:145-154.
- 406 MAURER, K. M., T. W. STEWART, AND F. O. LORENZ. 2014. Direct and indirect effects of
407 fish on invertebrates and Tiger Salamanders in prairie pothole wetlands. *Wetlands*,
408 34:735-745.
- 409 MIRANDA, L. E. 2005. Fish assemblages in oxbow lakes relative to connectivity with the
410 Mississippi River. *T. Am. Fish. Soc.*, 134:1480-1489.
- 411 PALMER, M. A., K. L. HONDULA, AND B. J. KOCH. 2014. Ecological restoration of streams
412 and river: shifting strategies and shifting goals. *Annu. Rev. Ecol. Syst.*, 45:247-269.
- 413 PFLIEGER, W. F. 1997. The fishes of Missouri, 2nd edition. Missouri Department of
414 Conservation Jefferson City, Missouri.
- 415 R CORE TEAM. 2020. R: A language and environment for statistical computing. R Foundation
416 for Statistical Computing, Vienna, Austria.
- 417 RODRIGUES, J. M. G. 2015. Cultural services in aquatic ecosystems. *Ecosystem Services and*
418 *River Basin Ecohydrology*, Springer, Dordrecht.
- 419 RONI, P., U. ABERG, AND C. WEBER. 2018. A review of approaches for monitoring the
420 effectiveness of regional river habitat restoration programs. *N. Am. J. Fish. Manag.*,
421 38:1170-1186.

- 422 RUETZ, C. R., D. G. UZARSKI, D. M. KRUEGER, AND E. S. RUTHERFORD. 2007.
423   Sampling a littoral fish assemblage: comparison of small-mesh fyke netting and boat
424   electrofishing. *N. Am. J. Fish. Manag.*, 27:825-831.
- 425 SCHILLING, K. E., K. KULT, A. SEEMON, K. WILKE, AND C. S. JONES. 2018. Nitrate-N
426   load reduction measured in a central Iowa restored oxbow. *Ecol. Eng.*, 124:19-22.
- 427 SCHILLING, K. E., K. KULT, K. WILKE, M. STREETER, AND J. VOGELGESANG. 2017.
428   Nitrate reduction in a reconstructed floodplain oxbow fed by tile drainage. *Ecol. Eng.*,
429   102:98-107.
- 430 SIMPSON, T. N., A. P. BYBEL, M. J. WEBER, C. L. PIERCE, AND K. J. ROE. 2019.
431   Occurrence, abundance, and associations of Topeka Shiners (*Notropis topeka*) in restored
432   and unrestored oxbows in Iowa and Minnesota, USA. *Aquat. Conserv.: Mar. Freshw.*
433   *Ecosyst.*, 29:1735-1748.
- 434 SNYDER, D. E. 2003. Invited overview: conclusions from a review of electrofishing and its
435   harmful effects on fish. *Rev. Fish. Biol. Fisher.*, 13:445-453.
- 436 STARK, W. J., J. S. LUGINBILL, AND M. E. EBERLE. 2002. Natural history of a relict
437   population of Topeka Shiner (*Notropis topeka*) in northwestern Kansas. *Trans. Kans.*
438   *Acad. Sci.*, 105:143-152.
- 439 TABOR, V. M. 1998. Final rule to list the Topeka Shiner as endangered. *Federal Register*
440   63:69008–69021. U.S. Department of the Interior, U.S. Fish and Wildlife Service,
441   Manhattan, K.S.
- 442 WARD, J. V., K. TOCKNER, D. B. ARSCOTT, AND C. CLARET. 2002. Riverine landscape
443   diversity. *Freshw. Biol.*, 47:517-539.

- 444 WITTE, C. C., M. L. WILDHABER, A. ARAB, AND D. B. NOLTIE. 2009. Substrate choice of
445 territorial male Topeka shiners (*Notropis topeka*) in the absence of sunfish (*Lepomis* sp.).
446 *Ecol. Freshw. Fish.*, 18:350-359.
- 447 ZALEWSKI, M., AND I. G. COWX. 1990. Factors affecting the efficiency of electric fishing.
448 *Fishing with electricity*. Fishing News Books Ltd., Blackwell Scientific Publications 89-
449 11.

TABLES AND FIGURES

TABLE 1. Oxbow morphology for (A) 128 oxbows from Iowa and Minnesota and (B) the 12 oxbows sampled during the sampling methods efficacy project.

Oxbows	Length (m)			Width (m)			Depth (m)		
	Average ($\pm$ SD)	Minimum	Maximum	Average ($\pm$ SD)	Minimum	Maximum	Average ($\pm$ SD)	Minimum	Maximum
A	107.6 $\pm$ 83.4	21	430	12.4 $\pm$ 5.6	3.1	35.1	0.54 $\pm$ 0.29	0.11	1.41
B	77.4 $\pm$ 39.8	23	139	10.0 $\pm$ 4.9	4.8	20.4	0.69 $\pm$ 0.13	0.56	0.98

TABLE 2. Abundance values for fish species captured in this study, including number of individuals in total and by sampling method, and its overall relative abundance (percent of total individuals). Values are based on 11 sampling events for each gear type in each wetland (18 May – 11 June).

Species	Total individuals	Percent of total	Numbers collected by sampling method			
			Backpack electrofishing	Fyke netting	Minnow trapping	Seining
Fathead Minnow <i>Pimephales promelas</i>	23877	72.66	554	5471	849	17003
Golden Shiner <i>Notemigonus crysoleucas</i>	2948	8.97	4	100	0	2844
Black Bullhead <i>Ameiurus melas</i>	1194	3.63	22	202	2	968
Brook Stickleback <i>Culaea inconstans</i>	1164	3.54	50	1083	4	27
Green Sunfish <i>Lepomis cyanellus</i>	1113	3.39	101	521	23	468
Common Shiner <i>Luxilus cornutus</i>	844	2.57	1	112	0	731
Brassy Minnow <i>Hybognathus hankinsoni</i>	816	2.48	5	202	2	607
Creek Chub <i>Semotilus atromaculatus</i>	262	0.80	11	88	9	154
Bluegill <i>Lepomis macrochirus</i>	222	0.68	32	33	0	157
Orangespotted Sunfish <i>Lepomis humilis</i>	106	0.32	7	6	0	93
White Sucker <i>Catostomus commersonii</i>	94	0.29	5	11	0	78
Bluntnose Minnow <i>Pimephales notatus</i>	58	0.18	1	52	0	5
Sand Shiner <i>Notropis stramineus</i>	39	0.12	1	37	0	1
Spotfin Shiner <i>Cyprinella spiloptera</i>	35	0.11	0	4	0	31
Largemouth Bass <i>Micropterus salmoides</i>	23	0.07	4	1	0	18
Black Crappie <i>Pomoxis nigromaculatus</i>	17	0.05	0	17	0	0
Hornyhead Chub <i>Nocomis biguttatus</i>	10	0.03	1	6	0	3

Table 2 Continued

Species	Total individuals	Percent of total	Numbers collected by sampling method			
			Backpack electrofishing	Fyke netting	Minnow trapping	Seining
Western Blacknose Dace <i>Rhinichthys obtusus</i>	8	0.02	0	1	0	7
Bigmouth Shiner <i>Notropis dorsalis</i>	7	0.02	0	6	0	1
Central Stoneroller <i>Campostoma anomalum</i>	6	0.02	1	3	0	2
Common Carp <i>Cyprinus carpio</i>	5	0.02	2	2	0	1
Johnny Darter <i>Etheostoma nigrum</i>	5	0.02	1	1	2	1
Yellow Perch <i>Perca flavescens</i>	3	0.01	2	0	0	1
Carmine Shiner <i>Notropis percobromus</i>	3	0.01	0	3	0	0
Topeka Shiner <i>Notropis topeka</i>	2	0.01	0	1	0	1
Rock Bass <i>Ambloplites rupestris</i>	1	0.00	0	0	0	1

TABLE 3. Descriptive statistics by sampling method for each quantitative metric. Overall mean ($\pm$ SD) and range values are based on 44 samples (11 wetlands x 4 sampling events per wetland).

Sampling Method	Species Richness	Total CPUE (no. fish per 100 m ²)	Fish length (mm)
Backpack Electrofishing			
mean $\pm$ SD	4.18 $\pm$ 3.03	22.79 $\pm$ 35.79	59.93 $\pm$ 34.81
Range	1 — 11	0.62 — 113.82	12 — 282
Fyke Netting			
mean $\pm$ SD	6.55 $\pm$ 4.23	293.65 $\pm$ 469.51	75.65 $\pm$ 37.51
Range	2 — 16	7.64 — 1383.28	21 — 375
Minnow Trapping			
mean $\pm$ SD	1.45 $\pm$ 0.82	47.15 $\pm$ 99.90	60.86 $\pm$ 13.87
Range	0 — 3	0 — 276.92	25 — 118
Seining			
mean $\pm$ SD	7.36 $\pm$ 4.82	449.37 $\pm$ 630.99	81.88 $\pm$ 40.75
Range	2 — 16	11.77 — 2114.04	15 — 360

TABLE 4. Pairwise contrast statistics for each sampling method (Total CPUE; catch per unit effort). P values are based on Tukey's adjustment for multiple comparisons. When a significant difference occurred ($P \leq 0.05$), the sampling method with the higher Total CPUE is indicated in bold text.

Contrast	Estimate	SE	Df	P
Fyke Netting – Seining	-0.570	0.485	27	0.65
Fyke Netting – Backpack Electrofishing	2.580	0.451	27	< 0.0001
Fyke Netting – Minnow Trapping	3.198	0.462	27	< 0.0001
Seining – Backpack Electrofishing	3.150	0.485	27	< 0.0001
Seining – Minnow Trapping	3.768	0.491	27	< 0.0001
Backpack Electrofishing – Minnow Trapping	0.618	0.479	27	0.58

TABLE 5. Pairwise contrast statistics for each sampling method (Species Richness). P values are based on Tukey's adjustment for multiple comparisons. When a significant difference occurred ($P \leq 0.05$), the sampling method with the higher Species Richness is indicated in bold text.

Contrast	Estimate	SE	Df	P
Fyke Netting – Seining	-0.143	0.249	27	0.94
Fyke Netting – Backpack Electrofishing	0.533	0.232	27	0.12
Fyke Netting – Minnow Trapping	1.382	0.237	27	< 0.0001
Seining – Backpack Electrofishing	0.676	0.249	27	0.05
Seining – Minnow Trapping	1.524	0.252	27	< 0.0001
Backpack Electrofishing – Minnow Trapping	0.849	0.246	27	0.0094

TABLE 6. Pairwise contrast statistics for each sampling method (10th-90th quantile length ranges). P values are based on Tukey's adjustment for multiple comparisons. When a significant difference occurred ($P \leq 0.05$), the sampling method with the higher average 10th-90th quantile length range is indicated in bold text.

Contrast	Estimate	SE	Df	P
Fyke Netting – Seining	-12.0	12.8	27	0.7830
Fyke Netting – Backpack Electrofishing	21.0	12.1	27	0.3259
Fyke Netting – Minnow Trapping	40.8	12.4	27	0.0141
Seining – Backpack Electrofishing	33.0	12.4	27	0.0598
Seining – Minnow Trapping	52.9	13.3	27	0.0025
Backpack Electrofishing – Minnow Trapping	19.9	12.6	27	0.4060

Fig. 1 Number of oxbows restored within Iowa, USA, per five-year period, 2001-2020.

Unshaded white bars represent oxbows restored during each five-year interval, and unshaded dark bars represent cumulative total.

Fig. 2 Map of the HUC8 basins in Iowa, USA, in which the study occurred.

Fig. 3 Length frequency distribution for lengths as sampled by each sampling method. Height of the shaded region for each sampling method along y-axis represents the frequency of fishes of that length.