



Native Mussel Conservation Concerns and Management Needs in National Parks of the Midwest Region



Top left: White heelsplitter (*Lasmigona complanata*) reintroduced in 2022 to the Cuyahoga River in Cuyahoga Valley National Park. *Top right:* Juvenile fatmucket (*Lampsilis siliquoidea*) propagated at Indiana Dunes National Park. *Bottom:* Overlooking agricultural fields bordering the confluence of Calf Creek (bottom left side of photo) and the Buffalo National River, which supports numerous native mussel beds.

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Science Report NPS/SR—2026/376

Jessica L. Joganic ¹, Brenda Moraska Lafrancois ²

¹ National Park Service
Buffalo National River
402 North Walnut Street, Suite 136
Harrison, Arkansas 72601

² National Park Service
Great Lakes Network Office
2800 Lake Shore Drive East
Ashland, Wisconsin 54806

Please cite this publication as:

Joganic, J.L., and B. Moraska Lafrancois. 2026. Native Mussel Conservation Concerns and Management Needs in National Parks of the Midwest Region. Science Report NPS/SR—2026/376. National Park Service, Fort Collins, Colorado. <https://doi.org/10.36967/2316514>

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Contents

	Page
Figures.....	v
Tables.....	vi
Appendices.....	vi
Abstract.....	vii
List of Acronyms	viii
Acknowledgments.....	ix
Introduction.....	1
Methods.....	4
Data Visualization and Analysis	5
Follow-up Webinar.....	6
Results.....	7
Multi-park Survey Responses.....	18
Follow-up Webinar Responses.....	19
Discussion	22
Major Findings and Recommendations.....	22
MWR Mussels in Context	27
Conclusions and Future Directions	31
Inventories of Mussel Species	31
Restoration of Degraded Habitats	31
Mitigation of Water Quality Threats	31
Prevention and Control of Invasive Species.....	31
Other Opportunities	32
Habitat Surveys	32
Mussel Reintroductions	32
Traditional Ecological Knowledge.....	32
Outreach Materials	32
Literature Cited	33

Figures

	Page
Figure 1. Map of the MWR and the park units, IMD networks, and mussel faunal provinces contained therein.	5
Figure 2. Important water resource types for native freshwater mussel habitat within MWR units.....	10
Figure 3. Water resource types at each MWR park that provide habitat for native mussels.....	11
Figure 4. Current knowledge and management of mussel presence within MWR units.....	12
Figure 5. Current knowledge and management of native mussel presence within MWR park units.....	13
Figure 6. Ranked threats to native freshwater mussels within MWR park units.....	14
Figure 7. The four most significant ecological threats to native mussel survival and reproduction in MWR parks.	15
Figure 8. Preference of park units to receive assistance from MWR staff.....	16
Figure 9. Composite bar chart of ranked forms of technical assistance related to native mussels that could be offered to park units by the Midwest Regional Office.	18
Figure 10. Examples of public education infographics incorporating state-specific native freshwater mussel data for Kansas (panel A) and Illinois (panel B).....	27
Figure 11. Panel maps of the ratings assigned by park units to the most commonly requested forms of technical assistance offered to them by the MWR.....	45
Figure 12. Panel maps of the ratings assigned by park units to the less commonly requested forms of technical assistance offered to them by the MWR.....	46
Figure 13. Screenshot showing summary of responses to questions one through three of real-time polls administered to participants during the follow-up webinar on 7 February 2024.....	47
Figure 14. Screenshot showing summary of responses to questions four through six of real-time polls administered to participants during the follow-up webinar on 7 February 2024.....	48
Figure 15. Screenshot showing summary of responses to questions seven and eight of real-time polls administered to participants during the follow-up webinar on 7 February 2024.....	49

Tables

	Page
Table 1. MWR park units that submitted native mussel survey responses.	7
Table 2. MWR park units that did not submit native mussel survey responses.	8
Table 3. Survey results ranking the types of threats faced by native freshwater mussels in MWR parks.	14
Table 4. Rankings of preferred forms of technical assistance regarding native mussel conservation offered by the regional office to MWR parks.	17
Table 5. Number of native mussels and number of species with conservation status, by state in the Midwest Region.	26
Table 6. Criteria for prioritizing native freshwater mussel conservation projects.	28

Appendices

	Page
Appendix A: MWR Native Mussels – Park Needs Survey	41
Appendix B: Technical Assistance Maps	44
Appendix C: Follow-Up Webinar Poll Question Results	47
Appendix D: Description of Supplementary Materials.....	50

Abstract

Over 300 species of freshwater mussels (order Unionida) are native to North America, and more than two-thirds of those are endangered, threatened, or of special conservation concern. Common threats include systematic habitat destruction and population fragmentation resulting from historic river impoundment, ongoing point source pollution and other factors contributing to water quality decline, competition with aquatic invasive species, and past large-scale consumptive use. Numerous population extirpations and species extinctions have been documented in recent decades, but because unionids are long lived, the full effect of these threats is expected to last well into the 21st century. There is a growing recognition among conservation professionals that active management of aquatic environments is needed to temper declines in mussel species abundance and diversity. Public lands are an area where freshwater mussel refugia could be developed and different management options evaluated for feasibility and efficacy. As a first step toward understanding the extent and magnitude of management concerns in relation to unionids within federally managed waterways, a short survey was administered to park units within the Midwest Region of the National Park Service. A total of 26 staff members at individual parks responded, as well as an additional three who submitted surveys on behalf of multiple units, such as the National Wild and Scenic River System.

Results indicate that mussel presence has been confirmed at 75% of responding units through either field observation or official species inventories. The greatest issue perceived by natural resource managers that threatens mussel population health and conservation in park units bordering the Great Lakes was identified as aquatic invasive species, while other parks in the Midwest cited either instream habitat degradation or water quality decline as the most urgent perceived concerns. The vast majority (80%) of responding parks requested technical assistance from the region, with the most common requests being for help with conducting species inventories, mussel habitat surveys, riparian habitat restoration, and reintroductions of native mussel species. The geographic distribution of submitted responses was examined to identify relevant patterns.

The purpose of this report is to provide both regional and park staff with a planning tool for designing conservation targets and identifying project partners. Survey results can be used in conjunction with species distributions documented across parks in the region to develop multi-unit funding proposals, monitoring programs, and management goals for improving the long-term viability of unionid populations located within freshwaters protected by the National Park Service.

List of Acronyms

AIS: Aquatic invasive species

APHN: Appalachian Highlands Network

BISO: Big South Fork National River and Recreation Area

CESU: Cooperative Ecosystem Studies Unit

GLKN: Great Lakes Network

HTLN: Heartland Network

IMD: Inventory and Monitoring Division

MWR: Midwest Region

NGPN: Northern Great Plains Network

NPS: National Park Service

NRSS: Natural Resource Stewardship and Science Directorate

NWSRS: National Wild and Scenic River System

SER: Southeast Region

T&E: Threatened and endangered

TEK: Traditional ecological knowledge

USFWS: United States Fish and Wildlife Service

USGS: United States Geological Survey

WSDARB: Big and Little Darby Creeks Wild and Scenic Rivers

Acknowledgments

Victoria Mendiola Grant (OZAR) and Shawn Hodges (BUFF) contributed comments during the formation of the survey utilized in this report and while drafting the manuscript. Joshua Dickey (INDU), Charles Morris (INDU), and Ryan Trimbath (CUVA) assisted during site visits and provided valuable insight to park needs and current actions. Julie Christian (SLBE), Susannah Erwin (Water Resources Division, WRD), Sue Jennings (retired NPS), and John Wullschleger (WRD) helped search for historic documents, and Abel Jordan (MWR) drafted the mussel research and resources bibliography. Finally, comments and suggested edits from three peer reviewers helped significantly to improve document clarity.

Introduction

Approximately 300 species of freshwater bivalve mollusks, or mussels, are native to North America, falling into one of two families—Unionidae or Margaritiferidae—within the order Unionida (Williams et al. 2017). Mussels are a part of the cultural and natural history of North America, serving as freshwater nutritional sources for humans and wildlife alike and performing a variety of vital ecological functions (Haag 2012). In many freshwater ecosystems, mussels dominate the benthic biomass and are critical for both habitat production (through substrate burrowing), riverbed stabilization, and the maintenance of aquatic food webs via sediment and nutrient cycling (e.g., Strayer 2017; Vaughn 2018).

As filter feeders, freshwater mussels are dependent on productive riverine or lacustrine ecosystems and are sensitive to deteriorating water quality. Additionally, they are long lived, sessile, and are obligate parasites of fish or salamanders during the larval (or glochidial) stage of their development (Haag 2012; Modesto et al. 2018). These unusual details of their ecology and life history make them excellent sentinel species for our freshwater habitats. Declining unionid populations signal a significant, on-going reduction in habitat availability, quality, and connectivity within and among rivers, lakes, and wetlands. Restoring freshwater habitats so that they support healthy mussel populations helps ensure lakes, rivers, and wetlands also continue to support healthy human populations. However, restoration can be challenging because we rely on these habitats for important ecosystem services, such as hydropower production, freshwater provisioning, recreation, flood mitigation, and sediment regulation (e.g., Griebler and Avramov 2015; Maltby and Acreman 2011; Sterner et al. 2020).

One of the biggest issues currently facing native freshwater mussels is population fragmentation due to extensive habitat destruction resulting from the creation of dams and other impoundment structures in the early part of the 20th century (Haag 2009). More recently, several inexplicable declines not easily attributable to commonly invoked causes—sedimentation, lack of fish hosts, eutrophication, overharvest—have wreaked havoc on some of the remaining mussel populations over a short time scale, causing the local collapse of entire assemblages (Haag 2019). Finally, the extinction debt that has been incurred due to habitat and population fragmentation related to historic and modern land use change, exploitation for the pearl and button industries, and the aforementioned anthropogenic pressures that have reduced both population size and landscape connectivity are projected to result in the extinction of more than 25% of the current North American mussel fauna in the coming decades (Haag 2009). In light of these issues, the ultimate goals of mussel conservation projects should include (1) maintaining existing healthy and genetically diverse populations, (2) establishing intact, stable, self-sustaining mussel assemblages that function together within a system and are resilient to both anthropogenic and climate change-induced impacts, and (3) restoring habitat conditions that support such populations. In the short term, many species have declined enough that propagation or translocation efforts to bolster rapidly declining populations and to reintroduce mussels to areas from which they have been extirpated are necessary (McMurray and Roe 2017). However, it is clear that propagation alone will not restore populations and that sustaining small,

isolated populations in perpetuity is neither desirable nor effective given current insufficiency in suitable habitat extent and connectivity. Most scientific publications on the topic of freshwater mussel conservation over the past two decades have emphasized that programs focused on habitat restoration coupled with a strong monitoring component are the most appropriate and promising methods for long-term success (e.g., Eveleens and Febria 2022; Haag and Williams 2014; Strayer and Dudgeon 2010).

As stewards of both public lands and waters and North American cultural and natural history, the National Park Service (NPS) is uniquely suited to contribute to native mussel conservation efforts via restoration of both riparian habitats and mussel populations. With over 910,000 acres designated as National Rivers, Lakeshores, and Wild and Scenic River units, the agency's protected waters provide refugia to common and threatened and endangered (T&E) mussel species alike (NPS 2024a). Additionally, given that more than 300 million people visited parks across the country in 2022 alone (NPS 2024b), public outreach and education performed by NPS staff represents a significant avenue to increase the public's exposure to the challenges faced by our freshwater ecosystems generally and native mussels specifically. For these reasons, parks have the capacity to affect a significant change in the course of projected extinctions of North American native freshwater mussels.

Recognizing the potential mussel conservation contributions to be made by the NPS, Sue Jennings (now retired from NPS) conducted a service-wide survey of mussel resources while working as Chief of Resources Management at Big South Fork National River and Recreation Area (BISO; Kentucky/Tennessee). She discovered significant native mussel presence in 27 park units located throughout every NPS region within the conterminous states (Jennings 1998) and determined that nearly 70 species were living within NPS-protected waters. Although the raw data and research notes from this survey are presently unaccounted for, her published report lays out a series of information, planning, and management needs for the protection of water quality and habitats within NPS units.

The Gulf Coast and Interior Basin regions of the southeastern United States are widely regarded as supporting the greatest concentration of freshwater mussel diversity and endemism (Graf and Cummings 2007). As such, more research has been conducted within states comprising the NPS Southeast Region (SER). For example, a monitoring protocol for tracking long-term mussel population trends has been established by the Appalachian Highlands Network (APHN) at both BISO and Obed Wild and Scenic River (Tennessee) (Emmott et al. 2018).

The second most important group of regions containing prime native mussel habitat are the Great Lakes and Mississippi and Missouri Basins, which are mostly covered by the states within the NPS Midwest Region (MWR). Less research has been conducted in park units within the MWR, but eight of the parks initially surveyed by Jennings (1998) reported native mussels within their boundaries at that time. Although additional units within the MWR have been surveyed for native mussel presence in the intervening years (e.g., Kelner and Davis 2008; Nichols et al. 2001, 2002, 2004; Perkins and Backlund 2000), no assessments of mussel conservation efforts across parks within the region have been conducted since the initial status report. Therefore, an update to these original data a quarter-century after publication of Jennings' findings and guidance was deemed timely and efficacious, and

a survey was administered to those MWR park units that contain both water resources and natural resource staff.

Jennings (1998) identified a number of management actions required for adequate protection of freshwater mussels in NPS units that run the gamut from acquisition of baseline inventory data to restoration of stream banks with native vegetation to development of watershed management plans with local communities and state agricultural agencies. Given the wide range of recommended options and the individual conditions that will make it impossible to execute some in certain park units, the goals of our report were twofold. First, we aimed to assess the needs of individual park units in managing native freshwater mussel resources based loosely on the list of management actions identified by Jennings (1998). Second, we intended to gauge regional interest in developing conservation projects on a larger, landscape-level scale and to identify corresponding themes that unite multiple park units according to shared mussel ecoregions and management goals. We address these goals in this report by analyzing survey responses for landscape distribution trends and make recommendations regarding next steps to take by the MWR towards native mussel conservation.

Methods

A survey of seven multiple-choice, rank-choice, and short-answer questions (Q1–Q7) was designed in Microsoft Forms (“MWR Native Mussels–Park Needs Survey”; Appendix A). Questions covered whether unionids are known to occur in park units and which water resources are important for them, the nature of threats that unionids experience in parks, and the forms of technical assistance requested by staff in relation to unionid conservation. The survey was administered to natural resource staff at individual MWR parks ($N = 43$; Figure 1), as well as the regional natural resource contacts for the MWR, three Inventory and Monitoring Division (IMD) networks, and the National Wild and Scenic Rivers System (NWSRS). In total, surveys were sent out to the 169 people on the MWR Natural Resource Stewardship and Science Directorate (NRSS) listserv who represented 1–3 individuals per park or regional program and varied in level of responsibility, including biological technicians, biologists, resource chiefs, park superintendents, and regional resource program leads.

The IMD networks of the NPS regularly collect natural resource data from park units to assess trends in biodiversity and biological health at the national, regional, and local scales (NPS 2023). The regional boundaries do not necessarily coincide with the IMD network boundaries, as the latter are based on shared ecology, geography, and natural resource characteristics. For example, the MWR park units are divided among four different networks: Heartland (HTLN, 15 units), Great Lakes (GLKN, 9 units), Southern Plains (SOPN, 1 unit), and Northern Great Plains (NGPN, 11 units). There are 13 units in the NGPN, but two of them (Fort Laramie National Historic Site/FOLA and Devils Tower National Monument/DETO) are subsumed within the Intermountain Region, instead of the MWR. Because the vast majority of NGPN parks are in the Midwest and there is some indication that both FOLA and DETO may harbor native mussels (Tronstad 2013, 2014), the survey was sent to natural resource staff at the NGPN to provide them with an opportunity to respond on behalf of all 13 park units within the network.

The NWSRS is a collection of rivers designated by Congress or the Secretary of the Interior for the protection and enhancement of their free-flowing condition, water quality, and outstanding remarkable values, such as recreation, fish and wildlife, geology, or culture (NWSRS 2023). Nine such rivers in the MWR are protected under the NWSRS and many are home to native freshwater mussels (e.g., Ohio Division of Wildlife 2022; Rivers, Trails, and Conservation Programs 1993; Szafoni et al. 2000).

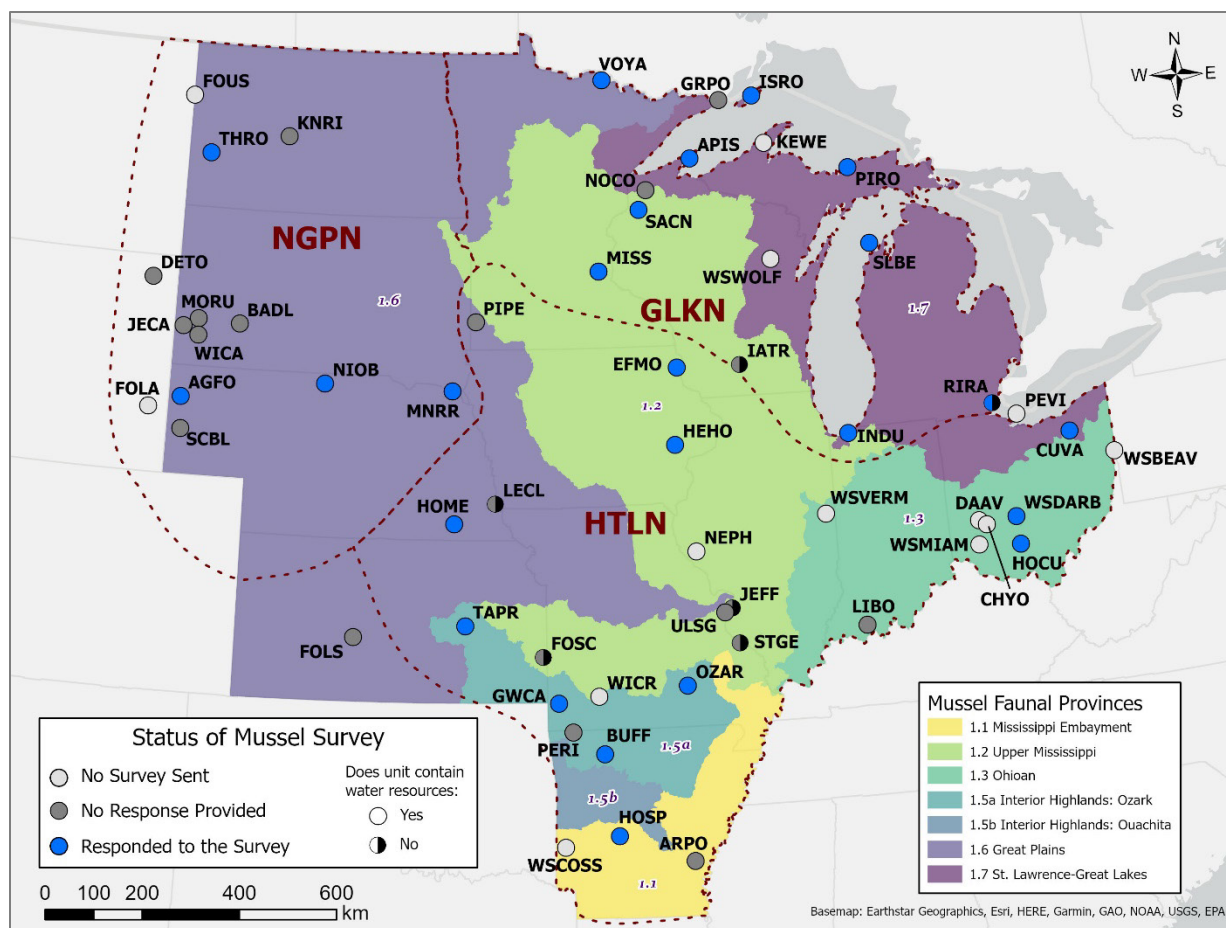


Figure 1. Map of the MWR and the park units, IMD networks, and mussel faunal provinces contained therein. Only the park units that house natural resource staff, those that include water resources, and the Wild and Scenic Rivers that are not also individual NPS units are shown ($n = 57$). Sites are classified as not being sent the MWR Native Mussels–Park Needs Survey (light gray circles, $n = 13$), received the survey but never responded (dark gray circles, $n = 20$), or received the survey and submitted a reply (blue circles, $n = 24$). Park units containing water resources are indicated by an open circle, while those without are indicated by a half-shaded circle. IMD networks are outlined in dark red dashed lines and labeled with their corresponding acronym (GLKN, Great Lakes Network; HTLN, Heartland Network; NGPN, Northern Great Plains Network). Mussel faunal provinces (pastel shading) are defined by Haag (2010) and are based on hierarchical cluster analysis of patterns of freshwater mussel faunal similarity across 126 North American watersheds.

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Data Visualization and Analysis

Survey responses were collated, and the responses from NPS regional and network staff (i.e., MWR, NWSRS, NGPN; hereafter referred to as “multi-park responses”) were set aside for separate review. Responses from the individual park units (hereafter referred to as “single-park responses”) were plotted with traditional data visualization techniques, such as bar charts and tree maps.

To examine geographic trends in single-park responses, the data were imported into ArcGIS Pro 3.1.2. They were joined to a point feature layer maintained by the NPS Land Resources Division

(https://services1.arcgis.com/fBc8EJBxQRMchlei/arcgis/rest/services/NPS_Land_Resources_Division_Boundary_and_Tract_Data_Service/FeatureServer), which is comprised of centroids for all park units contained within the NPS System as of October 2023. As geospatial data for NWSRS rivers are managed under a different system, the boundary information for any rivers that submitted single-park responses had to be imported into ArcGIS Pro from the U.S. Forest Service Geospatial Data Discovery Site (https://apps.fs.usda.gov/arcx/rest/services/EDW/EDW_WildScenicRiverSegments_01/MapServer/1). A centroid was calculated using the *Feature to Point* tool while constraining the location of the resultant representative point feature to be contained within the input polygon, which ensured that any geographic patterns were as visually accurate as possible. The river centroids were then appended to the feature layer of NPS park unit centroids and point feature symbology was sequentially altered to observe distribution patterns of single-park responses for all survey questions.

Finally, rank-choice questions were analyzed with a weighted scoring method that awards each candidate option a specified number of points corresponding to the number of alternative options rated lower. The Borda system was used—a consensus-based process that allows all information contained in a rank-choice survey to be used to select broadly acceptable alternative options rather than only those preferred by a majority (Saari 2023). Each alternative is awarded Borda points that are calculated as $n - r$, where n is the number of candidate options for that survey question and r is the rating of that option for a given survey response. In other words, for a question with four alternatives, the highest rated option receives $4 - 1 = 3$ points, the second rated option receives $4 - 2 = 2$ points, the third rated option receives $4 - 3 = 1$ points, and the lowest rated option receives $4 - 4 = 0$ points. Borda points are then summed across all single-park responses to provide a final score, or Borda Count, for that alternative option. The option with the highest Borda Count is considered the most preferred. In the case of a tied Borda Count, the option with the most #1 ratings from the single-park responses was determined to be the preferred one of the tied set. The Borda system has been shown to be the method most robust to common inaccuracies and paradoxes inherent to any of the various voting systems used to tally votes cast for more than two alternatives (Saari 2023).

Follow-up Webinar

J.L. Joganic hosted a webinar on 7 February 2024 to present results of the MWR Native Mussels—Park Needs Survey to park and region staff. Goals were to (1) share findings, (2) pose more specific follow-up poll questions to the participants, and (3) provide a collaborative space in which to share learned lessons or best practices developed by those parks that have experience in any aspect of the native mussel restoration process with those that have yet to start.

Results

In total, 29 survey responses were received. There were three multi-park and 26 single-park responses. One of the latter was from a unit of the NWSRS that is not associated with an official NPS park, Big and Little Darby Creeks (WSDARB). The remaining 25 are traditional park units administered by the NPS, although two parks (NIOB, HOCU) submitted multiple surveys from different staff members, so the actual number of individual parks that responded was 23, or 53% of the parks to which it was administered (Table 1). Eight of these units also responded to the survey conducted in 1997 by Jennings. All raw data survey responses are available upon request from B.M. Lafrancois.

Table 1. MWR park units that submitted native mussel survey responses. Park names are provided along with their associated abbreviations for units that responded to the 2023 MWR Native Mussels–Park Needs Survey. Units that also replied to the 1997 survey administered by Sue Jennings (NPS/BISO) and attended a follow-up webinar hosted by Joganic in 2024 are indicated.

Unit Code	Unit Name	Responded to 1997 Survey	Attended 2024 Webinar
AGFO	Agate Fossil Beds National Monument	No	No
APIS	Apostle Islands National Lakeshore	Yes	No
BUFF	Buffalo National River	Yes	Yes
CUVA	Cuyahoga Valley National Park	Yes	Yes
EFMO	Effigy Mounds National Monument	No	Yes
GWCA	George Washington Carver National Monument	No	No
HEHO	Herbert Hoover National Historic Site	No	No
HOCU ^A	Hopewell Culture National Historical Park	No	Yes
HOME	Homestead National Historical Park	No	Yes
HOSP	Hot Springs National Park	No	Yes
INDU	Indiana Dunes National Park	No	Yes
ISRO	Isle Royale National Park	No	No
MISS	Mississippi National River and Recreation Area	No	Yes
MNRR	Missouri National Recreational River	No	Yes
MWR ^B	Midwest Region	No	Yes
NWSR ^B	National Wild and Scenic Rivers System	No	No
NGPN ^B	Northern Great Plains Network	No	Yes
NIOB ^A	Niobrara National Scenic River	Yes	No

^A Units that had surveys submitted from two different employees. In both cases, one of the surveys at each unit was incomplete, so the complete survey was included in the analysis of single-unit responses. The other was reviewed for major discrepancies in multiple choice answers and the content of the answer to survey question 7 (Q7; see Appendix A).

^B Responses that represented multiple units and, therefore, were considered separately from the analysis of single-unit responses.

Table 1 (continued). MWR park units that submitted native mussel survey responses. Park names are provided along with their associated abbreviations for units that responded to the 2023 MWR Native Mussels–Park Needs Survey. Units that also replied to the 1997 survey administered by Sue Jennings (NPS/BISO) and attended a follow-up webinar hosted by Joganic in 2024 are indicated.

Unit Code	Unit Name	Responded to 1997 Survey	Attended 2024 Webinar
OZAR	Ozark National Scenic Riverways	Yes	Yes
PIRO	Pictured Rocks National Lakeshore	Yes	No
RIRA	River Raisin National Battlefield Park	No	No
SACN	Saint Croix National Scenic Riverway	Yes	Yes
SLBE	Sleeping Bear Dunes National Lakeshore	No	Yes
TAPR	Tallgrass Prairie National Preserve	No	Yes
THRO	Theodore Roosevelt National Park	No	No
VOYA	Voyageurs National Park	Yes	Yes
WSDARB	Big and Little Darby Creeks Wild and Scenic Rivers	No	No

^A Units that had surveys submitted from two different employees. In both cases, one of the surveys at each unit was incomplete, so the complete survey was included in the analysis of single-unit responses. The other was reviewed for major discrepancies in multiple choice answers and the content of the answer to survey question 7 (Q7; see Appendix A).

^B Responses that represented multiple units and, therefore, were considered separately from the analysis of single-unit responses.

According to the Hydrographic and Impairment Statistics database maintained by the Water Resources Division (<https://www.nps.gov/subjects/protectingwater/his.htm>), there are 45 total units within the MWR that contain water resources. Of these, survey responses are missing from 23 units (Table 2). However, only 15 of those units have dedicated natural resource staff that are members of the NRSS listserv and, therefore, received the native mussel survey. If there is interest by MWR to identify and conserve native mussel presence within all NPS-protected waters within the region, these parks should be included in any such inventory and management planning activities but will likely need increased support from the region given their lack of internal capacity to address aquatic natural resource needs.

Table 2. MWR park units that did not submit native mussel survey responses. These units contain water resources but either the survey was never administered to them (because no staff are members of the NRSS listserv) or a survey response was not returned.

Unit Code	Unit Name	Survey Administered
ARPO	Arkansas Post National Memorial	Yes
BADL	Badlands National Park	Yes
CHYO	Charles Young Buffalo Soldiers National Monument	No
DAAV	Dayton Aviation Heritage National Historical Park	No

Table 2 (continued). MWR park units that did not submit native mussel survey responses. These units contain water resources but either the survey was never administered to them (because no staff are members of the NRSS listserv) or a survey response was not returned.

Unit Code	Unit Name	Survey Administered
DETO	Devils Tower National Monument	Yes
FOLA	Fort Laramie National Historic Site	No
FOLS	Fort Larned National Historic Site	Yes
FOUS	Fort Union Trading Post National Historic Site	No
GRPO	Grand Portage National Monument	Yes
JECA	Jewel Cave National Monument	Yes
KEWE	Keweenaw National Historical Park	No
KNRI	Knife River Indian Villages National Historic Site	Yes
LIBO	Lincoln Boyhood National Memorial	Yes
MORU	Mount Rushmore National Memorial	Yes
NEPH	New Philadelphia National Historic Site	No
NOCO	North Country National Scenic Trail	Yes
PERI	Pea Ridge National Military Park	Yes
PEVI	Perry's Victory and International Peace Memorial	No
PIPE	Pipestone National Monument	Yes
SCBL	Scotts Bluff National Monument	Yes
ULSG	Ulysses S. Grant National Historic Site	Yes
WICA	Wind Cave National Park	Yes
WICR	Wilson's Creek National Battlefield	No

The water resources considered most important for providing habitat to native freshwater mussels in the MWR (survey question 2, Q2) are tributaries and wadable streams (20 parks) and mainstem rivers (13 parks; Figure 2). In all but two cases (RIRA, THRO), units that indicated mainstems were important also selected tributaries and wadable streams. Inland lakes and ponds were only considered important for mussels in the Ozark-Ouachita Region of Missouri and Arkansas, the Flint Hills of Kansas, and around the Great Lakes (Figure 3). The two units that selected the “Other” category did so to include groundwater-fed habitats (OZAR) and canals (CUVA) as important to the mussels found within their boundaries.

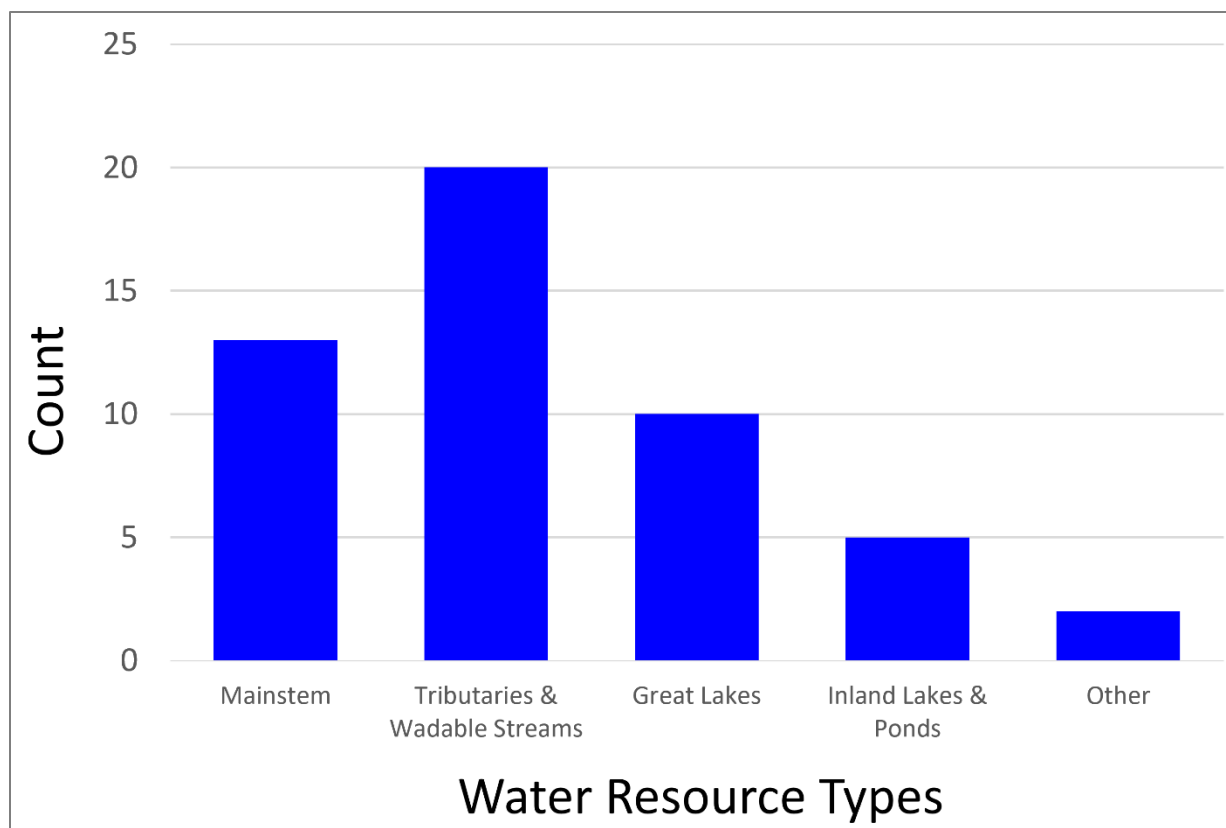


Figure 2. Important water resource types for native freshwater mussel habitat within MWR units. Survey responders were allowed to select more than one option. The “Other” category included resources such as canals and groundwater-fed habitats (springs).

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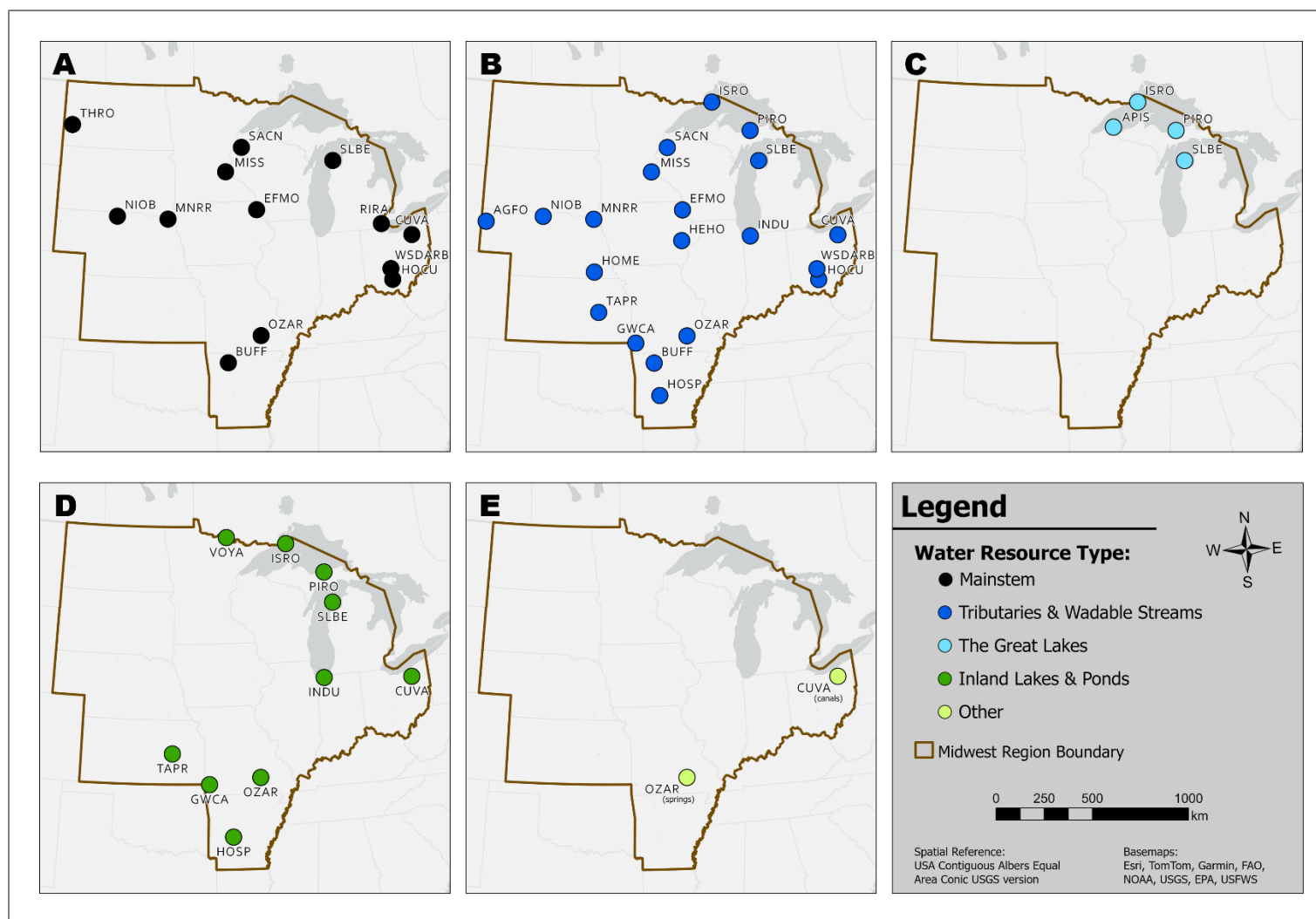


Figure 3. Water resource types at each MWR park that provide habitat for native mussels. Each panel contains a different resource type: (A) mainstem rivers, (B) tributaries and wadable streams, (C) the Great Lakes, (D) inland lakes and ponds, and (E) other. Additionally, the figure key shows the color-coding of the points in each panel and the scale that is common to all five. In panel E, the specific water type that is a significant “other” resource for native mussels is written below the park abbreviation with which it is associated.

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Most park units that responded to the survey have some knowledge of the native mussels in the park (survey question 4, Q4) because they have conducted a species inventory (N = 15). Of those, just over half are actively managing mussels within their boundaries (N = 8; Figure 4). Management was defined in this case to mean the occurrence of ongoing projects focused on mussel monitoring, research, conservation, or restoration. The greatest concentration of parks having completed some sort of native mussel survey is in the Great Lakes region (black and navy icons in Figure 5). Much less work has been done to inventory species presence in prairie states (light blue icons in Figure 5). Five parks were uncertain whether mussels were present (GWCA, HEHO, HOSP, RIRA, THRO), and these would be strong candidates for conducting future species inventories if there is local interest in developing mussel conservation initiatives. Finally, one park (AGFO) thought it unlikely that mussels were present because there are no water resources, the water resources present do not support mussels, or none were detected during surveys.

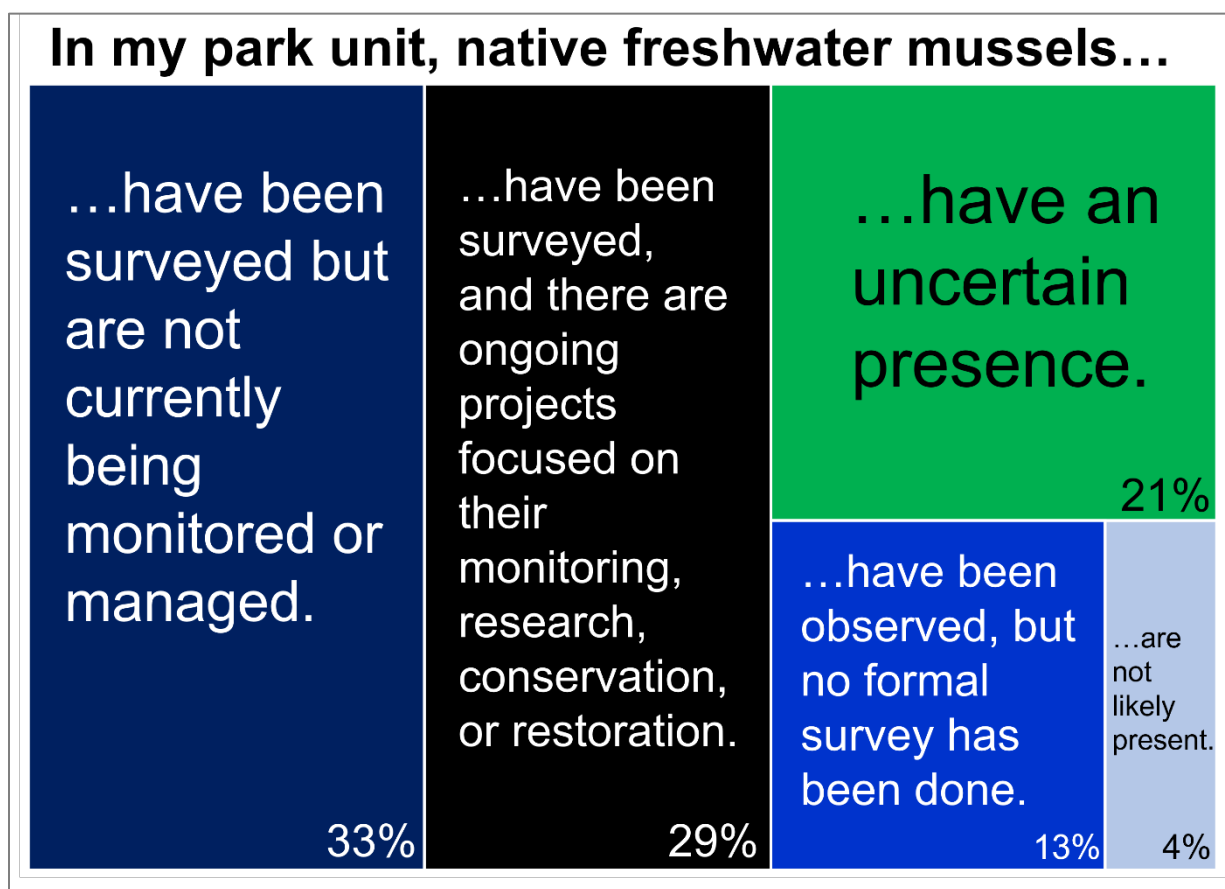


Figure 4. Current knowledge and management of mussel presence within MWR units. The five response options ranged from positive confirmation of mussel presence and active management to uncertain or even unlikely presence within the unit. The size of the rectangle in which the corresponding response is typed is proportional to the number of park units that selected that response, with the percentage of units having done so shown in the bottom right corner of each rectangle.

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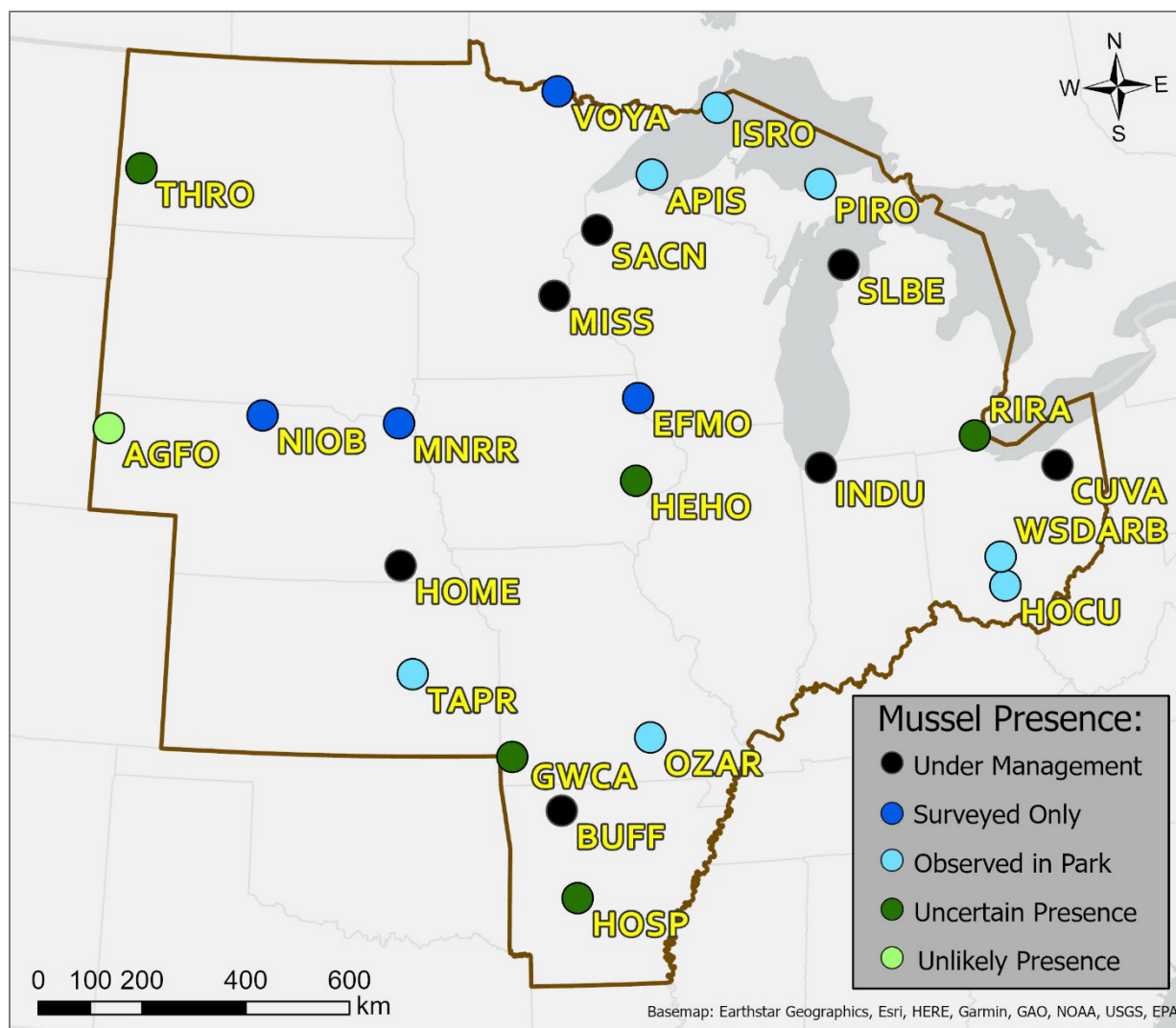


Figure 5. Current knowledge and management of native mussel presence within MWR park units. Symbols and color-coding are explained in the key in the bottom right corner of the map.

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Survey respondents were provided with eight options for types of threats potentially experienced by mussels and asked to rate them in importance from more (rating of 1) to less (rating of 8) important (survey question 3, Q3). The ratings were then converted into Borda points (see Methods, “Data Visualization and Analysis”), which were tallied to provide a Borda Count for each threat type. Both “instream habitat degradation” and “water quality decline” had the highest Borda Counts, but the former had slightly more #1 ratings, so it was ranked the greatest threat to MWR mussels (Table 3, Figure 6). However, it is important to note that “aquatic invasive species” (AIS) had the same amount of #1 ratings as instream habitat degradation, indicating that this was a major concern for some parks. Not surprisingly, those parks are located adjacent to or within the Great Lakes. (Quagga and zebra mussels were first introduced to North America from central Eurasia by ships using the Saint Lawrence Seaway [Benson 2013]. These two species are now established in all five Great Lakes.)

Similarly, mussel die-off events ranked low across all parks in aggregate but were rated as one of the top threats for a small subset of parks (HEHO, NIOB, OZAR, WSDARB).

Table 3. Survey results ranking the types of threats faced by native freshwater mussels in MWR parks. The Borda Count was used to rank threat types. The total number of #1 ratings that a threat received is provided to give an indication of the equal importance of aquatic invasive species (AIS) for a subset of parks, despite the threat being ranked fourth overall.

Types of Mussel Threats	Borda Count	Number of #1 Ratings	Rank
Instream habitat degradation	137	8	1 st
Water quality decline	123	7	2 nd
Hydrologic alterations	115	1	3 rd
Aquatic invasive species (AIS)	106	8	4 th
Fish host issues	92	0	5 th
Mussel die-off events	63	0	6 th
Harvest by humans	23	0	7 th
Other	13	0	8 th

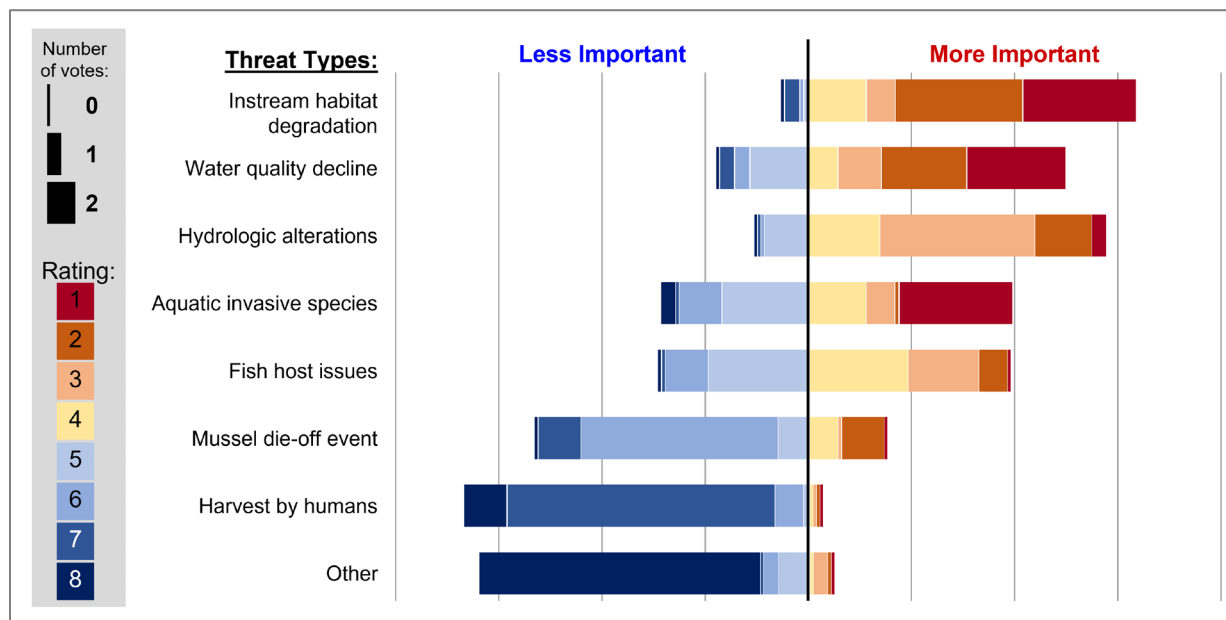


Figure 6. Ranked threats to native freshwater mussels within MWR park units. Rating of threats by survey responders is indicated by the color of each bar segment, with the key shown on the left side of the figure. The number of votes cast for a particular rating is indicated by the size of the bar segment, with examples of bar size for zero, one, and two votes shown in the top left. The threat types are ranked according to the Borda Counts (see Table 3) from top to bottom of the figure.

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The instructions for Q3 emphasized that the aim was for parks to identify their top three threats. The second and third ranked threats according to Borda Counts (water quality decline and hydrologic alterations) were consistent across survey results, but both instream habitat degradation and AIS were tied for the number of #1 ratings. Therefore, we elected to identify all four threats as regional priorities, with the specific focus for the top threat being geographically determined by proximity to the Great Lakes (Figure 7), as AIS was a top threat identified by Great Lakes parks while instream habitat degradation was of greater concern for parks located further from the Great Lakes.

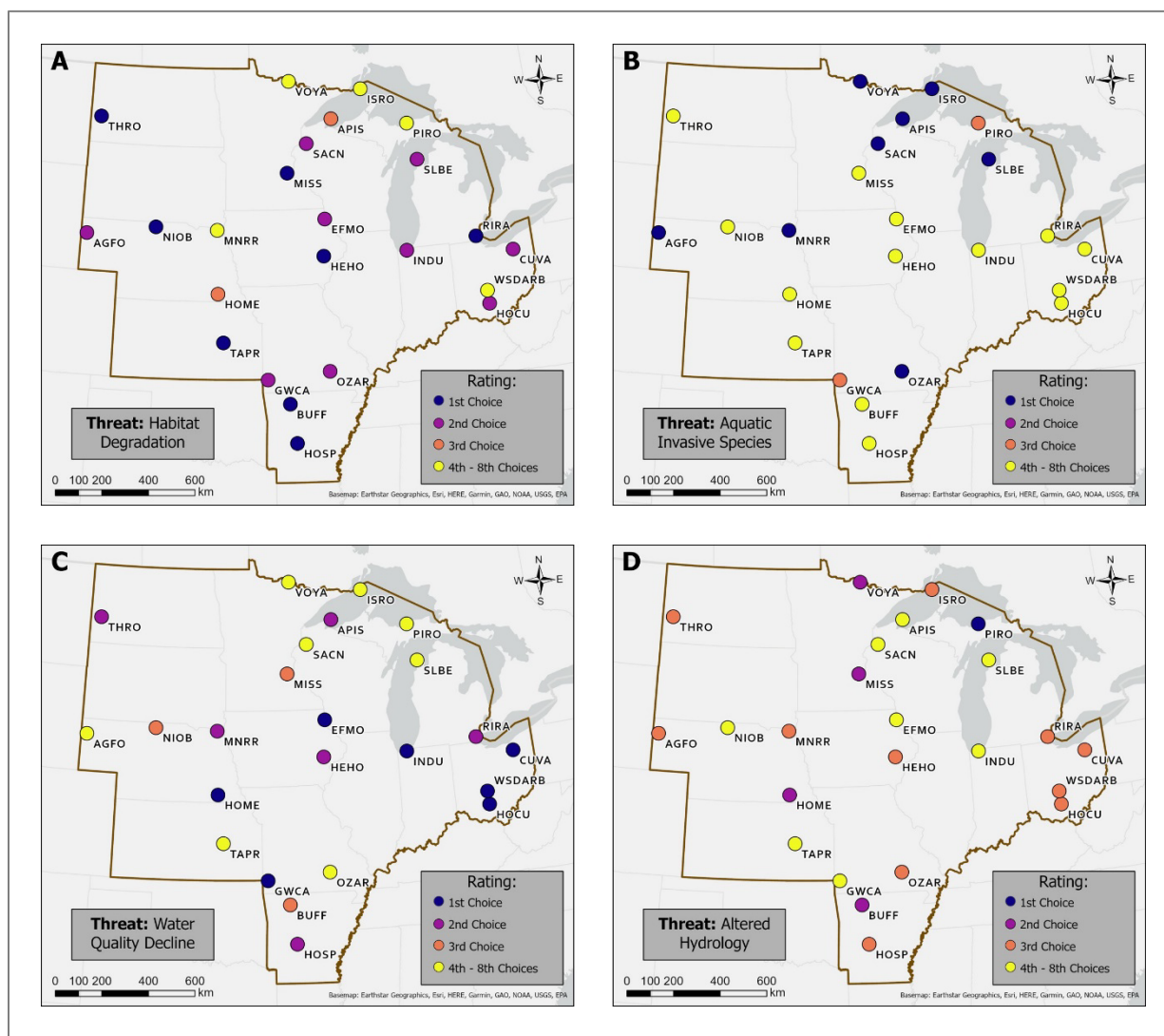


Figure 7. The four most significant ecological threats to native mussel survival and reproduction in MWR parks. Each panel indicates the ratings for a different threat: (A) instream habitat degradation, (B) AIS, (C) water quality decline, and (D) altered hydrology. For all panels, the color-coding of the point features is the same and indicated in the associated key.

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An important additional threat came to light upon reviewing the short-answer responses to the last question of the survey (Q7), which asked respondents to describe any additional native freshwater

mussel concerns or park specific needs not captured in the preceding questions. A few parks selected a relatively high rating (#3–#6) for the importance of “other” threats. At least one of those (TAPR) explained in their response to Q7 that drought and climate change-induced intermittent drying of water resources is a limiting factor for mussel survival and colonization. This is likely a factor to consider in other Great Plains parks and increasingly so elsewhere as climate change alters regional precipitation patterns. However, it is important to distinguish between artificial farm ponds (i.e., the type of inland water habitat available to native mussels at TAPR) and natural lentic habitats, as the two types might respond differently to changing climatic patterns.

The overwhelming majority of parks indicated that they would welcome any technical assistance offered by MWR staff (survey question 5, Q5; Figure 8). The few parks that declined assistance did so on the grounds that they are currently satisfied with existing partnerships and management efforts. Additionally, one of the two survey respondents for HOCU suggested that the unit currently lacks the capacity to accept any proffered aid, while the other indicated that aid would be welcome.

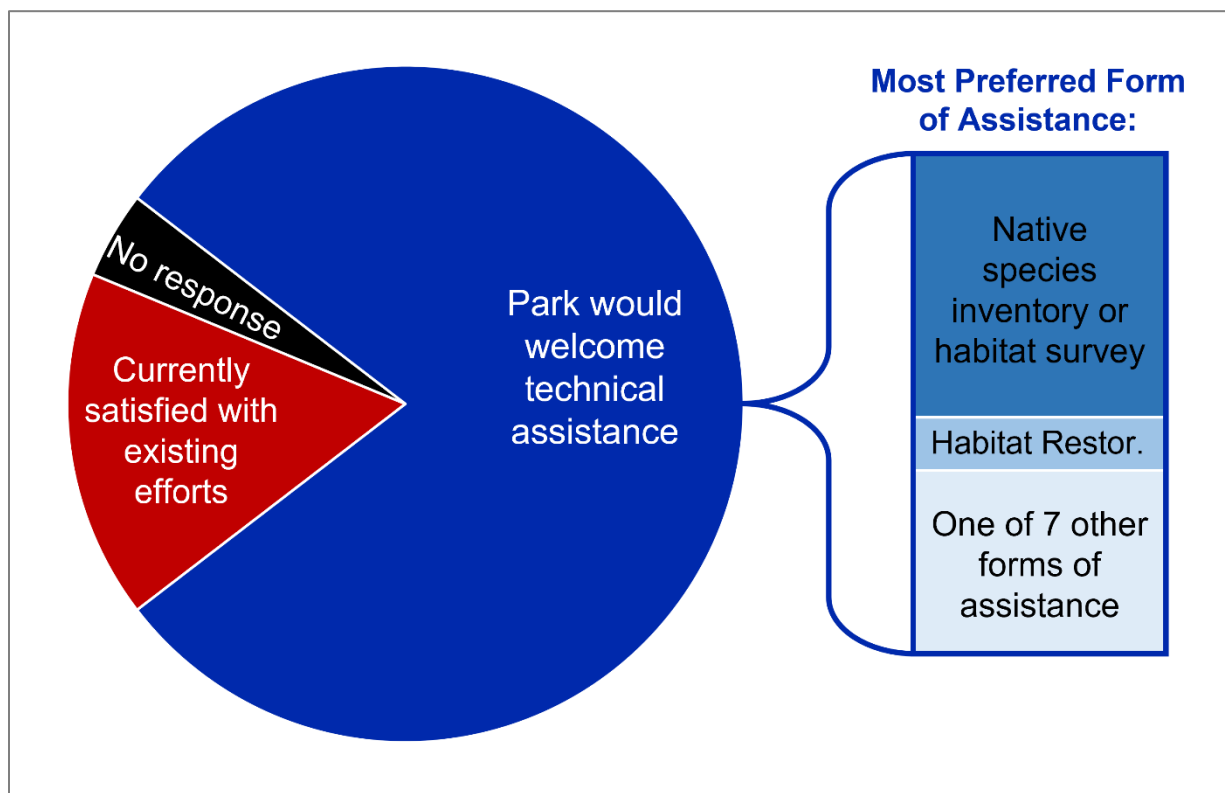


Figure 8. Preference of park units to receive assistance from MWR staff. The associated composite bar on the right shows the breakdown of parks answering “yes” to the question of proffered aid, indicating the relative preference of the three most requested forms of assistance.

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In terms of the forms of technical assistance most preferred by parks (survey question 6, Q6), both “native mussel species inventories” and “native mussel habitat surveys” had the highest Borda Counts, but species inventories received the greatest number of first-place votes from parks (Table 4,

Figure 9). The overwhelming majority of parks that rated species inventories #1 went on to rate habitat surveys as #2 (Appendix B). The maps provided in Appendix B can be used to identify clusters of parks that share common native freshwater mussel assemblages, concerns, and technical assistance preferences and, thus, would be good candidates for collaborative, multi-park projects and funding proposals.

Table 4. Rankings of preferred forms of technical assistance regarding native mussel conservation offered by the regional office to MWR parks. The Borda Count was used to rank assistance types. The total number of #1 ratings that each form of assistance received is provided to show how ties in Borda Counts were broken.

Types of Technical Assistance	Borda Count	Number of #1 Ratings	Rank
Native mussel species inventories	130	9	1 st
Native mussel habitat surveys	130	1	2 nd
Habitat restoration work	94	2	3 rd
Native mussel reintroduction	88	2	4 th
Host fish studies	84	1	5 th
Development of interpretation and education outreach materials	83	1	6 th
Identification of funding opportunities and development of proposals	81	2	7 th
Development of partnerships with local management agencies or research institutions	81	1	8 th
Assistance with T&E mussel recovery plans and management strategies	48	0	9 th
Review of compliance documents from a native mussel perspective	36	0	10 th

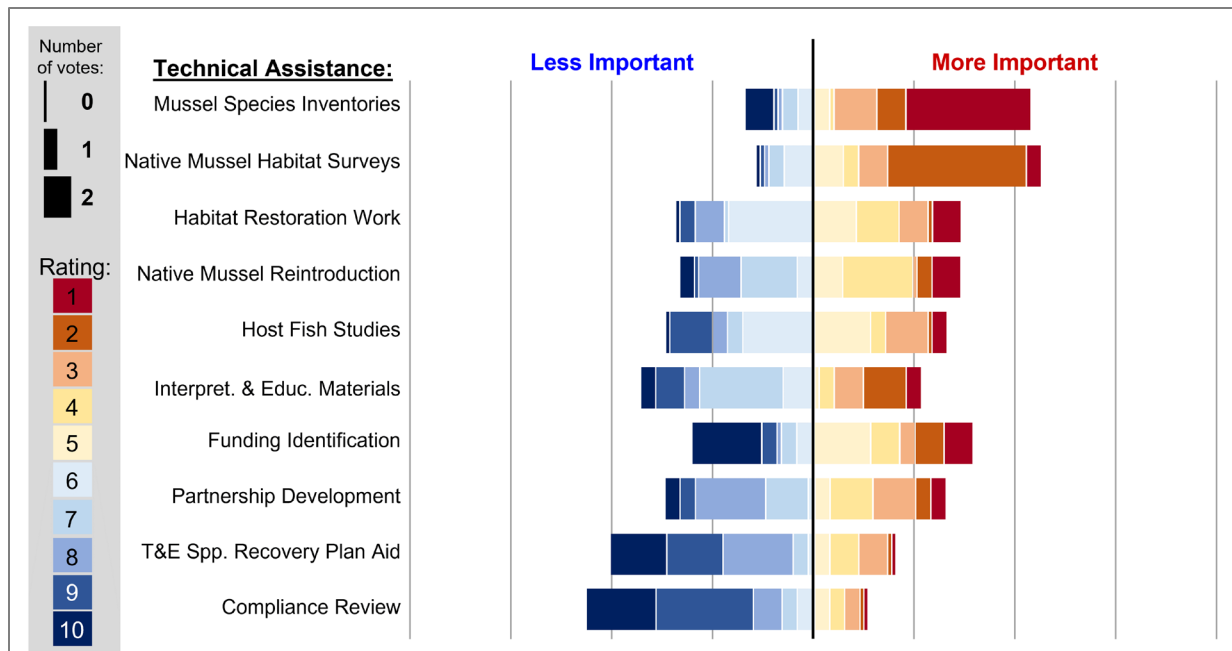


Figure 9. Composite bar chart of ranked forms of technical assistance related to native mussels that could be offered to park units by the Midwest Regional Office. The rating of assistance types by survey responders is indicated by the color of each bar segment, with the key shown on the left side of the figure. The number of votes cast for a particular rating is indicated by the size of the bar segment, with examples of the size for zero, one, and two votes also shown on the left. The assistance types are ranked according to the Borda Counts (see Table 4) from top to bottom of the figure.

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Multi-park Survey Responses

The three multi-park survey responses tended to be more general, as they reflected composite needs over a range of habitat types and geographic areas. Interestingly, the only survey response to identify “mussel die-off events,” also known as unexplained mass mortality events, as the top-rated threat to native freshwater mussels (Q3) was that submitted by the NWSRS. It is unknown whether this is related to (1) a stronger history of monitoring faunal populations in river segments during the designation process and thus a greater accumulation of data from which to identify such die-off events; (2) an increased emphasis on water-related resources in NWSRS units as compared to park units within the NPS system, which must also manage terrestrial resources and therefore have reduced capacity to focus singularly on trends within freshwater communities; (3) a feature of the NWSRS rivers themselves that contributes to increased frequency of such events; or (4) specifically the recorded mass mortality event of 2016 in Big Darby Creek rather than a feature common to multiple Wild and Scenic Rivers (Huitger et al. 2025). Following up on this finding with NWSRS staff to understand the nature of this survey response, as well as how die-off events impact mussel conservation in designated rivers within the region, is warranted. Although few mussel die-off events have been catalogued in NPS-managed rivers, several well-known examples exist from the MWR, SER, and Pacific West Region (PWR) that have been linked to potential pathogenic causes (Richard 2023). The US Fish and Wildlife Service (USFWS) and US Geological Survey (USGS) are actively

collecting information about emerging mussel die-off events, and information about any such events should be directed to them to aid in the development of diagnostic tools for screening propagated mussels and identifying die-off triggers (Leis et al. 2018; D. Waller, *pers. comm.*).

The MWR multi-park survey response to Q3 was also interesting in that it identified “fish host issues” as the second most highly rated threat to native mussels across the region, yet only two single-park survey responses answered similarly (ISRO, PIRO) and none indicated that threat as their primary concern. The reason for this result can only be surmised, but it could reflect a difference in conservation priorities as related to spatial scale (park vs. region) or time scale (immediate needs vs. long-term goals). This finding suggests a need for increased communication between parks and the MWR to ensure solutions proposed or advocated at a regional level meet the needs of and support the programs being implemented at a local level. It would be informative to follow-up with parks to clarify whether the indicated “fish host issues” are related to a lack of known fish hosts in the watershed, a lack of knowledge of specific fish hosts for local native mussels, barriers to fish movement throughout the system in question, or something else entirely.

Finally, it became apparent that the native mussel-related needs of parks in the western portion of the MWR are generally different from those elsewhere in the region. The NGPN multi-park survey response indicated that the top five preferred forms of technical assistance (Q6) were: (1) development of interpretive and educational outreach materials, (2) development of partnerships with local management agencies or research institutions, (3) mussel reintroduction, (4) native mussel species inventories, and (5) native mussel habitat surveys. This was reflected in the single-park survey responses for NIOB, but not MNRR, both of which are within the NGPN and responded individually to the survey. MNRR identified native mussel species inventories and native mussel habitat surveys as the top two preferred forms of technical assistance. These were the two forms most requested among parks in other portions of the MWR.

This difference is likely explained by the fact that NIOB is depauperate of mussel fauna, while MNRR still supports at least a portion of its historic mussel assemblage (Hoke 2011). Parks that have a longer history of native mussel work (e.g., BUFF, MISS, SACN) or those with small or non-existent assemblages (e.g., CUVA, NIOB, TAPR) tended to prioritize reintroduction, host fish studies, and administrative tasks (e.g., funding requests, compliance review, T&E recovery plans).

Follow-up Webinar Responses

Participants of the follow-up webinar included staff from most of the park units that responded to the survey (see Table 1), as well as three that did not (BADL, LIBO, PIPE). In total, 54 people attended the webinar, representing 17 individual park units, three IMD Networks, and the MWR NRSS leadership team. Eight questions were asked of participants using the Microsoft Teams polling feature (Appendix C).

Poll results indicate that many parks have strong existing mussel partnerships, but several are interested in establishing new ones, including HOCU, HOSP, and PIPE. As all three are located in states with long histories of native mussel surveying (Ohio, Arkansas, and Minnesota, respectively),

state agencies might make good partners for mussel survey protocols. Additionally, all three are also near other park units that have conducted prior surveys and are currently undertaking updated surveys or targeted conservation projects with the help of their own university or state agency collaborators (CUVA, BUFF, and MISS, respectively). Inter-park sharing of knowledge might be a valuable pursuit in this context. It was mentioned in the chat that Cooperative Ecosystem Studies Units (CESU) Network coordinators could help parks identify potential university or research institute partners.

Adequately explicating the direct management implications when applying for NRSS Inventories and Assessment funding is one of the most important components determining whether an inventories project is scored favorably. To assess what roles inventory data might play in meeting parks' resource management goals, we asked participants to identify how they might use such data. Multiple response selections were allowed. There were 23 respondents, and the overwhelming majority of them said mussel inventory data could be used for determining sites appropriate for potential restoration/reintroduction (19 votes) and for informing compliance and environmental review activities (17 votes). Assessing T&E species presence (15 votes), the degree of change since a previous mussel inventory was conducted (11 votes), and the impact of a stressor such as a flood or AIS introduction on mussel populations within park boundaries (nine votes) were also popular.

Twenty-six respondents selected from a list of climate vulnerabilities that they considered relevant to native mussels in their park units. Responses reflected a concern about the potential for increased water temperature (19 votes) and reduced flow volume (18 votes) to impact mussel populations, as well as seasonal hydrologic changes in the form of increased precipitation (14 votes). Using the chat feature, participants also raised some less obvious climate concerns such as the effects of wildfire-related erosion and changes to road salt use within the surrounding watershed.

About half of the 16 participants who responded to the question about the need for mussel reintroduction said their park had a present need (seven votes) and half said they foresaw a future need for such efforts (eight votes). Only one park saw no need for mussel reintroduction (BADL), likely due to focusing management efforts on other taxa and the relative dearth of river miles within the park's boundaries.

In terms of in-stream habitat concerns, participants were asked to select which mussel-related habitat issues were most important at their park; multiple selections were allowed. The 18 responses indicated that parks were concerned about numerous elements: sedimentation (13 votes), bank erosion (11 votes), habitat fragmentation (seven votes), channelization (five votes), and "other" (two votes), which were then clarified to be water temperature (BUFF) and a combination of historic legacy effects and bed stability (CUVA).

One of the questions posed to webinar participants asked which AIS were of greatest concern at their parks, with options including *Corbicula*, dreissenids, vegetation, fish, "other," "not sure," and "AIS are not a concern at my park." The majority of the 21 respondents indicated dreissenids (11 votes). Each of the other options received 0–3 votes each, with *Corbicula* being of concern to OZAR, BUFF,

and TAPR. Specifically, respondents highlighted a lack of knowledge of how *Corbicula* presence impacts native mussels and whether the spread of this particular AIS would eventually reach the northwestern parks in the region.

Webinar participants were also asked to identify the factors that have most likely caused their park's water quality issues. Respondents were allowed to select multiple options. There were 42 responses from 13 respondents, and almost all indicated non-point source runoff (11 votes) and increased sediment load (nine votes). Point source runoff and changing temperature regimes each received seven votes and contaminants received six votes. Two votes were cast for "other" and none for "no known water quality issue in our park."

Finally, the webinar also presented an opportunity for NPS staff concerned with native mussel conservation to identify colleagues at other parks who are similarly concerned and to share any experiences that they have had thus far in managing mussel populations and/or habitats. The parks currently pursuing in-house (INDU) or partner-based (CUVA, FOLA) propagation offered a few remarks on their experiences with the process thus far. Additionally, interest was expressed by multiple webinar participants regarding the proposed endangered species listing of the salamander mussel (*Simpsonaias ambigua*; USFWS 2023). This is relevant because the USFWS considers the salamander mussel a priority species within the Great Lakes region. Any participants interested in pursuing a potential collaboration with USFWS were directed to contact B.M. Lafrancois.

Discussion

Major Findings and Recommendations

Within MWR parks, riverine habitats such as mainstem rivers and tributaries are the most common that provide habitat to freshwater mussels throughout the region. In fact, every respondent park except for two (APIS, VOYA) indicated either or both as potential mussel habitat within their boundaries. However, inland lakes and ponds provide important habitat for a subset of parks in the Great Lakes region as well as a small number of Ozark and prairie parks. While restoration of riverine habitats is typically emphasized in the native mussel conservation literature (Haag and Williams 2014), it is important to keep in mind that other sources of freshwater also can be important mussel habitats and that these sources may require different methods of habitat restoration (e.g., Meerhoff and de los Ángeles González-Sagrario 2022; Sayer 2014).

The status of park mussel conservation efforts varies widely across the MWR. Multiple parks, particularly those concentrated in the middle part of the region, are uncertain about mussel presence or composition and would benefit from an initial species survey. A handful of parks ($n = 6$: CUVA, FOLA, HOME, INDU, MISS, SACN) have ongoing mussel management programs, and their published work provides excellent examples of prior mussel inventories, habitat surveys and restoration projects, fish host work, and reintroduction projects. For example, inventory and population status assessments were conducted for a group of Great Lake parks (ISRO, PIRO, SLBE) in the early 2000s by the USGS, providing a baseline against which future landscape distribution and community composition changes can be compared (Nichols et al. 2000, 2001, 2004). The native mussel survey currently underway at SLBE could assess species abundance, diversity, and distribution changes at the park over the last quarter century. Additionally, if the raw data from Jennings' earlier survey efforts are ever recovered, changing attitudes in native freshwater mussel management needs over the past 25 years can be evaluated for the subset of parks that responded to both Jennings' and the current native mussel surveys.

In addition, reintroduction projects are currently underway at several parks from which the entire mussel faunal assemblage was extirpated in the past century (CUVA, FOLA, HOME, INDU). Although the lessons learned during the reintroduction process will be valuable for other parks in the region looking to follow suit in the future, it is important to keep in mind that parks with extant native mussel populations have additional considerations about genetic compatibility between extant and introduced stock populations: outbreeding depression—a reduction in fitness resulting from the crossing of genetically distinct populations—should be avoided wherever possible (Frankham et al. 2011). However, parks with extirpated assemblages should still be diligent and ensure genetic compatibility, as the coevolution of native mussels and their host fish has been shaped by shared microenvironments (Douda et al. 2017). Additionally, reintroduction efforts in fish have provided evidence that local adaptation of source populations has structured their genetic diversity and likely contributes to the success or failure of reintroduction efforts (Shi et al. 2022; White et al. 2023). It is entirely possible the same is true for native mussel populations as well, as evidence is mounting that anthropogenic changes to freshwater habitats have contributed significantly to intraspecific genetic

differentiation within and among watersheds (e.g., Geist and Kuehn 2004). Consequently, genetic compatibility will become an increasing priority concern for restoration work moving forward.

Parks expressed significant concern about two threats: instream habitat degradation and water quality. Studies to better understand these two threats and develop management options would benefit mussels in many parks. Although much remains to be elucidated regarding environmental factors that influence mussel growth and reproduction, recent research is beginning to fill in knowledge gaps. Importantly, these gaps are also of interest more broadly outside of park boundaries, as the role that native mussels play in maintaining healthy aquatic ecosystems is becoming more widely recognized among both the general public and broader scientific community (e.g., Bloomquist 2025; Farrington 2022; Šverclová 2024). We recommend looking to Bakshi et al. (2023) for the most comprehensive and systematic review of the impact of water quality on freshwater mussels that we were able to locate. These authors identified gaps between known requirements for mussels and current water regulations, thereby allowing them to develop recommendations for monitoring and ameliorating poor water quality measures. This is a valuable source of information that lists minimum levels required to observe a negative impact on mussel health and reproduction of multiple sources of habitat degradation, including sediment toxicity, flow regime, temperature, contaminants, turbidity, and common nutrients.

There are many potential avenues where small-scale restoration measures could benefit mussel populations. For example, research was conducted at SACN on nutrient conditions in river and lake environments within the park, the impact of those conditions on the quality of food available to mussels, and the effect of food quality on mussel growth and survival (Bartsch et al. 2017). Results indicate that nitrogen and phosphorus levels influence the composition of the phytoplankton community, which impacts the abundance of high-quality food for mussels. Additionally, cyanobacteria presence also limits successful mussel foraging. While we do not yet know exact dietary requirements for native freshwater mussels generally—certainly not for individual species—the results of Bartsch et al. (2017) suggest that improving water quality and minimizing cyanobacteria concentrations, which are likely to increase with predicted changing climate patterns, will benefit mussel populations.

Invasive species emerged as a top priority for a subset of parks in the Great Lakes region, the Missouri River Basin, and at OZAR. This suggests that the current regional emphasis on AIS management, including invasive mussel detection and control, is warranted from a native mussel standpoint (e.g., Karns 2020; Lafrancois et al. 2022). Participants of the follow-up webinar expressed concern about knowledge gaps concerning AIS spread and the impact of *Corbicula* on native mussel populations. Future outreach efforts by the MWR could focus on providing park natural resource staff with information briefs covering AIS known information and management lessons learned by parks already affected by AIS invasions (e.g., Lafrancois et al. 2022; McDowell et al. 2014). As the greatest method of controlling invasions is to actually prevent them in the first place, outreach emphasis should be placed on public education and preventing the spread of all types of AIS.

Interestingly, Great Plains parks mentioned that other invasive species were of greater concern than the more common ones, such as *Corbicula* and *Dreissena*. AGFO mentioned that the presence of pale-yellow iris (*Iris pseudoacorus*), Canada thistle (*Cirsium arvense*), and northern pike (*Esox lucius*) compromises the river and floodplain, thus greatly impacting its ability to support mussel reintroductions. Some parks within the region are concerned with didymo algal blooms (*Didymosphenia geminata*). All of these will impact water quality and the ability of native mussels to colonize and survive yet typically receive less attention than do the exotic bivalves. Another useful future avenue to explore would be assessing just how systemic a problem these other nuisance species present and identifying funding sources for early detection and rapid response that are not specifically earmarked for quagga/zebra mussels.

Concerns over hydrologic alterations were noted for several widely dispersed parks, likely for a range of reasons including dam operations/water level management and climate change. From a proposal development standpoint, it would be useful to explore each of these threats in further detail via a follow-up survey to interested parks. The impact of each of these factors on native mussel diversity, abundance, growth, and survivorship has been assessed (e.g., Allen et al. 2013; Barnett and Woolnough 2021; Galbraith and Vaughn 2011; Hastie et al. 2003; Pandolfo et al. 2012; Sethi et al. 2004). Although there may be limited capacity within parks to affect change in mussel habitats through dam removal or altering hydroelectric operations, there are some examples within the MWR of both, including removal of the Brecksville Dam in CUVA (EPA 2024) and changes to the daily flow regime of St. Croix Falls Dam in SACN (Sansom et al. 2013). Partnerships among federal agencies can be leveraged as well, as is shown through a recent Candidate Conservation Agreement with Assurances between USFWS and the Lower Colorado River Authority. This voluntary 20-year agreement will manage water operations in a manner beneficial to the conservation of resident freshwater mussels (Buzek 2023). These examples demonstrate that more extreme conservation actions to benefit native mussels are possible under the right circumstances.

A strong majority of parks noted that they would welcome technical assistance support on native mussel issues. However, many of these technical assistance needs are nuanced and park specific. Overall, native mussel inventories and habitat surveys were the most preferred forms of assistance requested. Multiple small HTLN parks (EFMO, HOME, HOSP, HOCU) ranked mussel surveys as their top issue, as did two GLKN parks (PIRO, VOYA), several river parks (MNRR, OZAR, SACN), and WSDARB. There are currently mussel inventories underway at OZAR and SLBE in conjunction with university partners, inventories at SACN and PIRO launched during summer 2025, and an inventory of the small parks noted above is slated to begin in 2026. However, several past surveys have noted that regular repeat efforts should be undertaken to monitor population changes, particularly given projected impacts related to changing climate, landscape use, and AIS (e.g., Lafrancois et al. 2022; Shearer et al. 2005). Long-term monitoring datasets are invaluable for determining whether management actions are producing sustainable mussel populations. Opportunities for multi-park mussel inventories should be explored for future funding via the IMD's Inventories and Assessment program or a Service-wide Comprehensive Call. This is particularly important, as several parks indicated that they are within the range of at least one T&E species but have not yet been able to confirm their presence within park boundaries (EFMO, HOSP, MNRR).

Habitat surveys were a high priority for many parks throughout the region. An ongoing collaboration between the USGS Columbia Environmental Research Center, Arkansas State University, BUFF, and OZAR is currently developing geomorphologic and hydraulic habitat quality metrics with the goal of modeling future habitat changes and identifying potential refugia for freshwater mussel within these two river parks. Other such projects across the region can be modeled after this one, especially as USGS staff are transferring technical knowledge to park staff as part of the process. The background shading in Figure 1 and in Appendix B depicts mussel faunal provinces defined by similarity in mussel assemblage, as influenced by local hydrology, geology, and climate (Haag 2010). These provinces can be used to identify networks of parks with both similar mussel assemblages and management needs. For example, both BUFF and OZAR are in *Province 1.5a – Interior Highlands: Ozark Plateau*, along with TAPR. Any insights gained during this USGS-NPS mussel habitat survey may be more readily transferrable to TAPR than to other parks.

Habitat restoration was a top choice for two river parks that bracket the MWR (BUFF, MISS). During the follow-up webinar, natural resource staff at these parks identified both “sedimentation” and “bank erosion” as major concerns with instream habitat degradation. Recently, bank erosion has been shown in estuarine environments to seriously impact filtration services performed by local mussels (Pinton and Canestrelli 2024). Given the differences in local geology, regional climate, and level of urban development at each park, the restoration techniques required to address these interrelated concerns likely will be different. However, this makes them excellent candidate parks in which to initiate a coordinated and systematic approach to the habitat restoration process. As long as sufficient baseline data are collected and appropriate long-term monitoring protocols are implemented, a wealth of information can be gleaned from such a project to be applied in the future to other parks. Such an approach of piloting large-scale, complex projects in a subset of parks with disparate conservation needs and environmental conditions is an excellent example of combining adaptive management and evidence-based conservation approaches, which has recently been advocated as a way to combine these seemingly incongruent philosophies, thereby harnessing the power of both (Gillson et al. 2019).

Mussel reintroduction was listed as a top priority for two widely dispersed parks (CUVA, TAPR). Most parks rated assistance with mussel reintroduction as a moderate priority (i.e., 4th to 7th). To further clarify park vision in this regard, we included a poll question in the follow-up webinar asking participants to indicate whether they see a need for mussel reintroduction at their park. Sixteen individuals responded: presently/yes, right now (seven votes); yes, eventually (eight votes); and no (one vote). Five parks are currently undergoing reintroduction work—primarily those that have lost most or all of their native mussel assemblages at some point in the 20th century or are working to conserve T&E species: CUVA, FOLA, HOME, INDU, and SACN. Drafting a case study briefing from these parks of lessons learned during these efforts can help inform future reintroductions in other parks. Furthermore, we provide a list of facilities within the Southeast and Midwest that offer mussel propagation services for a variety of native species (Appendix D).

Development of interpretive and educational materials was listed among the top priorities for several parks in the southern and eastern parts of the MWR and would likely be widely useful as outreach

material for increasing public awareness surrounding the threats that native mussels face. Further discussion with parks is needed to determine what types of information and products would be most useful. However, using the information provided in Table 5, state-specific infographics can be created to assist in this endeavor (Figure 10).

Table 5. Number of native mussels and number of species with conservation status, by state in the Midwest Region. Only extant native mussel species within each state according to the most current data available as of 2024 are included. Data were drawn from published state mussel guides or websites maintained by a state's natural resource department (see Appendix D).

State	Native Mussels	State Endangered	State Threatened	State Special Concern
Arkansas ^A	84	11	13	20
Illinois	67	21	3	11
Indiana	62	11	0	14
Iowa	43	8	6	0
Kansas	40	7	4	11
Michigan	44	15	4	12
Minnesota	48	13	10	5
Missouri ^A	68	14	7	9
Nebraska ^A	25	8	3	5
North Dakota	15	3	3	4
Ohio	59	23	5	11
South Dakota ^A	15	2	3	3
Wisconsin	53	11	8	5

^A Since a complete list of state-listed species was unavailable for this state, the NatureServe SRank (state rank; <https://www.natureserve.org/>) was used according to the following equivalency key: S1 = state endangered, S2 = state threatened, S3 = state special concern.

Several parks (NIOB, ISRO, several in Ohio, the NWSRS and NGPN units) are interested in identifying and building native mussel partnerships. During the follow-up webinar, participants were asked to further clarify which agencies are the ones with which they have existing partnerships. There were 19 respondents, each of which was allowed to select multiple answers. The number of votes cast for each of the options was as follows: state agency (10), USFWS (8), USGS (4), university (7), “other” (1), “no partnership in place but we’d like to develop one” (4), “no partnership in place and we don’t need one at this time” (2). The “other” partners that were indicated included the Environmental Protection Agency, the Army Corps of Engineers, ecological consultancy firms, municipal divisions, and the National Park Foundation.

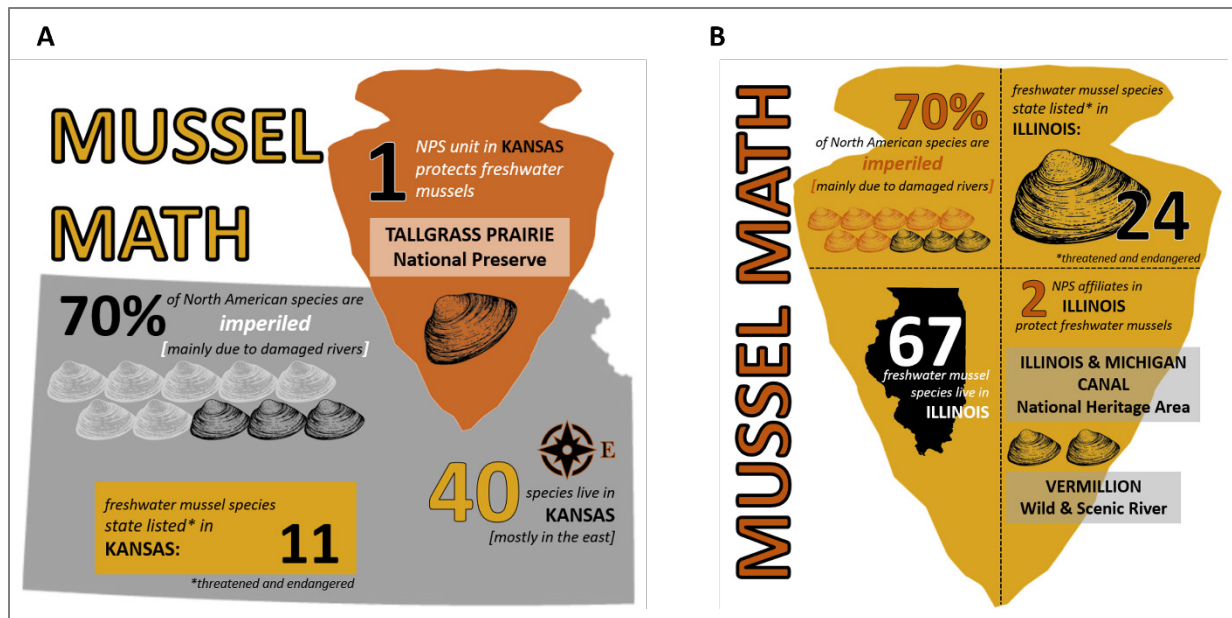


Figure 10. Examples of public education infographics incorporating state-specific native freshwater mussel data for Kansas (panel A) and Illinois (panel B).

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A list of malacologists that work throughout the MWR and can be contacted with questions about native mussels is provided in the supplemental materials accompanying this report (Appendix D). This list was created by augmenting the point of contact lists for both mussel protocols and propagation facilities provided on the website of the Freshwater Mollusk Conservation Society (FMCS; <https://molluskconservation.org/About.html>). Individuals were included if they are primarily located in the Midwest or western portions of the Southeast and have either published surveys in the academic and gray literature or have served on the board of the FMCS. The hope is that fruitful new partnerships can be developed with these individuals and the organizations for which they work.

MWR Mussels in Context

In acknowledgment of the plight faced by North American mussels and to meet the growing need for proactive conservation planning, the National Native Mussel Conservation Committee was formed in the mid-1990s to develop a *National Strategy for the Conservation of Native Freshwater Mussels* (hereafter referred to as the National Strategy), which was published in 1998 and updated in 2016 (FMCS 2016; NNMCC 1998). The National Strategy is focused around ten identified problems and associated strategies for addressing them, including a lack of knowledge about basic mussel life history and population distributions, degradation of quality mussel habitat, threats posed by AIS, and a lack of awareness or concern among officials, academics, and the general population about the need for mussel conservation on a national scale. Given that the NPS bridges the gap between environmental stewardship and public interface, the agency is uniquely positioned to address this last problem identified by the National Strategy through outreach and education. Native mussel conservation is a massive problem nationally that will require the cooperative efforts of multiple agencies, interpretation and resource management staff, and park visitors. Some parks in the MWR

with known mussel resources are good examples of incorporating a strong interpretation component in their native mussel conservation program (e.g., CUVA, HOCU, MISS, SACN).

In addition to enumerating a list of ten priority conservation issues on which to focus research and funding efforts, the original National Strategy provided a series of useful criteria for prioritizing alternative conservation projects in the face of limited time, effort, and funding (Table 6). Given the great number of remaining unknowns regarding native mussel presence and conservation needs within the MWR, it will be incredibly useful to use such a decision framework for prioritizing the many projects needing to be developed across the region.

Table 6. Criteria for prioritizing native freshwater mussel conservation projects. Criteria were identified in the National Strategy (NNMCC 1998), which covers proposed projects and activities addressing mussel management concerns and conservation goals. Criteria are not provided in a specific order because not all criteria will apply to every project. Mussel conservation strategies and projects should be designed and selected to best fit the regional needs and park goals.

Index	Criterion
1	Project has partners or has the potential to create partnerships.
2	Project work is related to priorities for geographical distribution and species diversity and considers the degree of threat.
3	Project addresses both the status and trends of the mussel populations.
4	Project focuses on the aquatic system within the watershed (e.g., USGS quadrants).
5	Project fulfills the objectives of existing management or recovery plans.
6	The project is feasible and achievable (i.e., cost-effective; uses the best choice of methods).
7	Project does not necessarily duplicate existing studies.
8	Project provides a short-term solution until a long-term plan is developed, or itself offers a long-term solution.
9	Project has a monitoring component.
10	Projects that prevent extinction are of a higher priority than projects that maintain existing populations, and maintenance projects are of a higher priority than recovery projects.
11	All other options have been explored (e.g., habitat restoration or translocation).
12	Applicability of research to multiple species (national research receives a higher priority than local research).

A common finding of systematic reviews of the freshwater mussel conservation literature is that few reports detailing the efficacy of restoration measures exist, which makes it challenging to decide on best management practices and standard operating procedures (e.g., Eveleens and Febria 2022; Strayer and Dudgeon 2010). This concern was also raised in the response from HOME to Q7, which offered park staff an opportunity to describe additional native mussel concerns or specific park needs. The published literature emphasizes that restoration measures will only be successful, repeatable, and useful to others if practitioners clearly state restoration objectives in a quantitative manner and collect suitable data to evaluate success, including measuring an appropriate comparator, whether that is a pre-restoration site, matched control, or something else (Eveleens and Febria 2022).

It is important to note that any actions the MWR elects to take to advance a regional native mussel conservation program can and should be built on the existing paradigms that others have developed. In particular, we highlight the research and conservation framework put forth by Bouska et al. (2018). After documenting current management practices across state agencies and assessing common conservation challenges and needs, they designed a program for Missouri “whereby habitat needs are identified, risks are assessed, and standardized protocols are developed to monitor and detect trends in mussel assemblages and threats.” They acknowledge that resource limitations are a major constraint in many local and federal agencies and argue that their program is “amenable to alternative situations dependent on the mussel fauna and the nature of associated threats.” This suggests that the program is robust to modification and scalable, such that it could act as a foundation from which to design similar programs across the region or within individual park units.

Additionally, the USGS has a strong record of scientific research on and expertise in native mussel health, biology, and ecology that the MWR should leverage during the conservation development process. Specifically, the agency has published a science vision document with the intended purpose of guiding practitioners who are planning mussel conservation projects and of facilitating partnerships among stakeholders (Newton et al. 2023). This document contains some valuable insights and resources the MWR could draw upon while considering next steps in regional native mussel conservation planning. Furthermore, several joint programs encourage intra-agency collaboration and the application of USGS-provided science to NPS-identified management issues. The USGS Natural Resources Preservation Program and USGS/NPS Water-Quality Partnership are two such programs that could provide funding to both increase our understanding of native mussel threats within parks and begin to address specific concerns, such as habitat restoration and population augmentation.

In addition to native mussel work in some MWR parks (e.g., SACN, MISS), there are several good examples in the SER. The APHN has an established monitoring protocol to track mussel restoration efforts at several SER parks (Emmott et al. 2018). This could be adapted by HTLN, NGPN, and GLKN to ensure consistency across parks in the region. Such standardization would be similar to the international standards established for monitoring the freshwater pearl mussel (*Margaritifera margaritifera*) that were published by the European Committee for Standardization (Boon et al. 2019). Both the SER and European protocols contain recommendations for assessing native mussel and host fish population health, tracking water quality, and evaluating parameters of physical habitat structure.

Because MWR parks are at different stages of the mussel conservation process, knowledge transfer among parks is vitally important. Identifying alternative strategies for overcoming park-specific challenges can be achieved more easily if a framework for information exchange and relevant data storage is established. We have developed a support tool for making conservation action decisions in the form of a flowchart (see Appendix D, Supplemental Materials). Parks can reference this flowchart to identify the stage at which their mussel conservation is currently and which steps to take next based on their goals. Depending on the species present within a park, not all steps will be relevant. Importantly, one of the foundational steps of the process (Step I: identifying whether and

which types of mussels are present) is lacking for many parks, a fact that is underscored by the number of respondents to our survey that rated a native mussel inventory as a priority need. To that end, there is a companion to the current report that is forthcoming (Joganic et al. [*in prep*]) and will provide parks with a baseline list of native mussel species present within their park boundaries and surrounding watershed based on crowd-sourced data. There are also several supplementary materials included with the current report to assist in the planning and implementation of mussel conservation projects (see Appendix D).

A few additional concerns arose in the Q7 responses that have not yet been discussed. First, a few park units indicated that the current lack of park-based natural resource staff in general and aquatic expertise specifically has been a hindrance to addressing native mussel conservation concerns. Although numerous parks in the MWR are home to terrestrial ecologists and biologists, there are relatively fewer aquatic ecologists, a fact that is highlighted by the percentage of MWR parks that contain water resources yet have no aquatic staff on the NRSS listserv (17%; see Table 2). Regional and network-based aquatic staff have experience with native mussel monitoring and may be increasingly important resources for parks seeking to pursue mussel conservation opportunities.

Second, it was surprising that only one park explicitly indicated that they felt they lacked knowledge of mussel distribution within park boundaries that would be important for adequately assessing necessary mitigation measures during infrastructure project implementation. Given that only 19 of the units that responded have conducted a native mussel inventory at some point in the past and only 11 of those were within the last decade, it is likely that this gap in knowledge also impacts other parks during infrastructure construction. Identifying mussel locations within NPS-protected watersheds is important for both planning conservation projects and protecting existing populations during the execution of other management activities.

Finally, the Q7 response from MISS brought up the unique perspective that “there’s also a gap in agency knowledge of traditional ecological knowledge and a need for stronger partnerships with local indigenous communities in relation to native mussel communities and host fish.” There is precedence within NPS for developing natural resource management approaches that incorporate traditional ecological knowledge (TEK) and even some examples internationally and in the Pacific Northwest for TEK-based mussel conservation projects (Henn et al. 2011; Michel et al. 2019; Quaempts et al. 2018). The results of the survey that we administered demonstrate that there is a burgeoning interest in expanding the knowledge base for addressing native mussel concerns. Carving out space to incorporate TEK into future planning and data acquisition efforts through targeted interviews, active partnership development, or experiential learning, as has been done for climate change (e.g., Vinyeta and Lynn 2013), can only enrich the suite of conservation and restoration tools at our disposal.

Conclusions and Future Directions

We conducted a survey of management concerns and needs regarding native freshwater mussel conservation within MWR park units. Several threats to mussel population health and survival were identified and common themes emerged from the results concerning desired forms of assistance from regional staff. Based on our findings, we make the following recommendations to help develop targeted science and restoration projects to address the top concerns for many parks.

Inventories of Mussel Species

It was clear from survey results that there is a strong desire from parks across the region to inventory the native mussels present within their watersheds. Several projects are currently underway or in the works, but several smaller parks (EFMO, HOCU, HOME, HOSP) expressed an interest in being considered for future inventories after seeing the results of this project during the follow-up webinar. We expect the interest in native mussel conservation to continue to grow and for such inventory requests to become increasingly common. MWR staff can help coordinate and manage such projects to ensure consistency of methodology and efficient distribution of resources among parks.

Restoration of Degraded Habitats

Habitat concerns were often associated with bank erosion. Although erosion is one of several natural fluvial geomorphological processes related to the dynamic nature of rivers, atypical or excessive bank erosion related to the loss of riparian vegetation, stream channelization, watershed disturbances from cattle trampling, or other such anthropogenic disturbances often increases bed load beyond a level to which riverine flora and fauna can adapt. It would be helpful to inventory known bank erosion issues across MWR parks to determine instances where erosion should be considered atypical or excessive. We should explore the possibility of establishing long-term monitoring systems to track such instances of bank erosion, and proposals for mitigation or restoration work will need to be developed where appropriate. This will likely require technical assistance from Water Resources Division geomorphologists who have recently summarized best practices for managing bank erosion within national parks (Field et al. 2025).

Mitigation of Water Quality Threats

Although numerous sources of water quality concerns exist, the most common one mentioned by survey respondents was non-point source runoff. Unfortunately, this can be difficult to manage, so it would be beneficial to follow up with parks who ranked this highly to refine their scope and needs. Thereafter, watershed management projects could be developed to address such concerns. The Section 319 Nonpoint Source Management Program maintained by the Environmental Protection Agency is one potential funding source that supports efforts to invest in strategies to address water quality concerns.

Prevention and Control of Invasive Species

Invasive species were a big concern for a smaller subset of parks, but the path forward is dependent on the species implicated. Specifically, due to the relatively large number of parks that indicated concern over the presence of dreissenids and to the fact that the routes of entry to the MWR for these

AIS are from the northeast part of the region, it would be prudent for the Great Lakes parks to continue to conduct early detection, monitoring, and control efforts for dreissenids. Conversely, given that the focus of other parks is on AIS other than dreissenids, parks in the Great Plains and Ozarks should concentrate on both evaluating the potential impacts of species such as invasive non-native plants and fish and identifying methods of preventing their establishment within park boundaries.

Other Opportunities

Habitat Surveys

Ongoing habitat survey work being done at BUFF and OZAR can be built upon and applied to other interested parks. Methods used to evaluate geomorphologic and hydraulic habitat characteristics for native mussels can be used to identify and subsequently protect suitable habitat elsewhere. This will help ensure that when mussel populations begin to recover or are re-established, there are quality habitats to which they can return.

Mussel Reintroductions

Similarly, continued mussel reintroduction efforts at numerous MWR parks where mussel populations were previously decimated can be compared using case study methodology to elucidate lessons to apply during future endeavors at other parks. Additionally, showcasing NPS mussel reintroductions more broadly can improve general knowledge about an ostensibly less charismatic group of animals and garner public support for these individual projects. Perhaps the greatest challenge for NPS in relation to mussel propagation for reintroduction is identifying the role that the agency should fill in the process, which may involve working with state, federal, and academic partners to increase propagation efforts.

Traditional Ecological Knowledge

Engaging with tribal partners on upcoming mussel inventories emerged as one potential method of improving management outcomes. We recommend making the effort to explore traditional tribal relationships with freshwater mussels. In particular, parks that are interested in developing interpretation themes around historic use of mussels on the landscape should consider incorporating TEK into the planning process.

Outreach Materials

Finally, numerous parks voiced a desire to develop appropriate outreach materials. We have provided examples of potential infographics that could be adapted for specific needs. Furthermore, success stories from any of the aforementioned topics would make excellent fodder for additional outreach materials. Continuing to highlight these endeavors in regional resource publications, such as *The Confluence: Midwest Region Natural and Cultural Resources Highlights*, helps ensure parks across the region are kept abreast of any conservation advances made.

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Appendix A: MWR Native Mussels – Park Needs Survey

A survey of seven multiple-choice, rank-choice, and short-answer questions was administered to Midwest Region parks through Microsoft Forms. Respondents completed the survey online. Examples of the introductory statement and questions asked are provided below. The questions asked begin with the letter “Q” and the options for answering those questions are provided below them.

Introduction: Native freshwater mussels are vital to maintaining aquatic habitat and water quality, but face threats in many MWR parks. Responses to the following survey questions will be used to clarify native mussel information needs, threats, and management interests in your parks, and identify opportunities for multi-park collaborations.

Q1. Please list your home park or work unit.

- Users provided with a text box to type their answer.

Q2. Identify the water resource types most likely to provide habitat for native mussels in your park (select all appropriate).

- Users presented with list of six checkbox options:
 1. Medium or large mainstem rivers,
 2. Small tributaries or wadable streams,
 3. Inland lakes or ponds,
 4. The Great Lakes,
 5. My park has no water resources,
 6. Other.

Q3. Please rank the following threats by order of importance to native freshwater mussels at your park (drag cells up or down to rank, noting that the aim is to identify your top 3 threats; there may be ties further down the list).

- Users presented with eight topics, which they physically moved on the screen to place in order of priority (highest to lowest). Topics were:
 1. Water quality degradation (e.g., non-point source run-off, contaminants, etc.);
 2. In-stream habitat degradation (e.g., sedimentation, channelization, habitat fragmentation);
 3. Hydrologic alterations (e.g., streamflow modification, dams, etc.);
 4. Fish host issues (e.g., loss of host fish, declining/unhealthy host fish populations, or barriers to host fish movement);

5. Aquatic invasive species;
6. Mussel die-off events;
7. Harvest by humans;
8. Other.

Q4. How would you characterize the state of knowledge in your park when it comes to native freshwater mussels?

- Users selected one of five possible checkbox responses:
 1. Native freshwater mussels are not likely present in my park (e.g., there are no water resources, our water resources don't support them, or none were detected during surveys).
 2. I am uncertain whether native freshwater mussels are present in my park.
 3. Native freshwater mussels have been observed in my park, but no formal survey has been done.
 4. Native freshwater mussels have been surveyed in my park but are not currently being monitored or managed.
 5. Native freshwater mussels have been surveyed in my park and there are ongoing projects focused on their monitoring, research, conservation, or restoration.

Q5. Are you interested in receiving technical assistance with native mussel conservation in your park in the next five years?

- Users selected one of three possible checkbox responses:
 1. Yes, we would welcome assistance in addressing native mussel issues in our park.
 2. Thanks, but our park is satisfied with existing partnerships and management efforts.
 3. No, we don't need assistance at this time (e.g., due to lack of native mussel resources, lack of staffing capacity, etc.).

Q6. If you answered "yes" above, please rank the following types of assistance in order of what would be most useful to you in the next five years (drag cells up or down to rank, noting that the primary aim is to identify your top 3 needs; there may be ties further down the list).

- Users presented with ten topics, which they physically moved on the screen to place in order of priority (highest to lowest). Topics were:
 1. Native mussel species inventories;

2. Native mussel habitat surveys;
3. Habitat restoration work (rivers, riparian zones, streambanks, etc.);
4. Host fish studies (e.g., surveys of host fish presence, distribution, and abundance or studies to determine host fish for key mussel species);
5. Mussel reintroduction;
6. Development of interpretive and educational outreach materials;
7. Development of partnerships with local management agencies or research institutions;
8. Assistance with T&E mussel recovery plans and management strategies;
9. Review of compliance documents from a native mussel perspective;
10. Identification of funding opportunities and development of proposals.

Q7. Please describe any additional native mussel concerns or specific park needs not captured above.

- Users provided with a text box to type their answer.

Appendix B: Technical Assistance Maps

Panel maps were created to show the ratings each park assigned to the forms of technical assistance offered to them by the Midwest Regional Office (Figures 11 and 12).

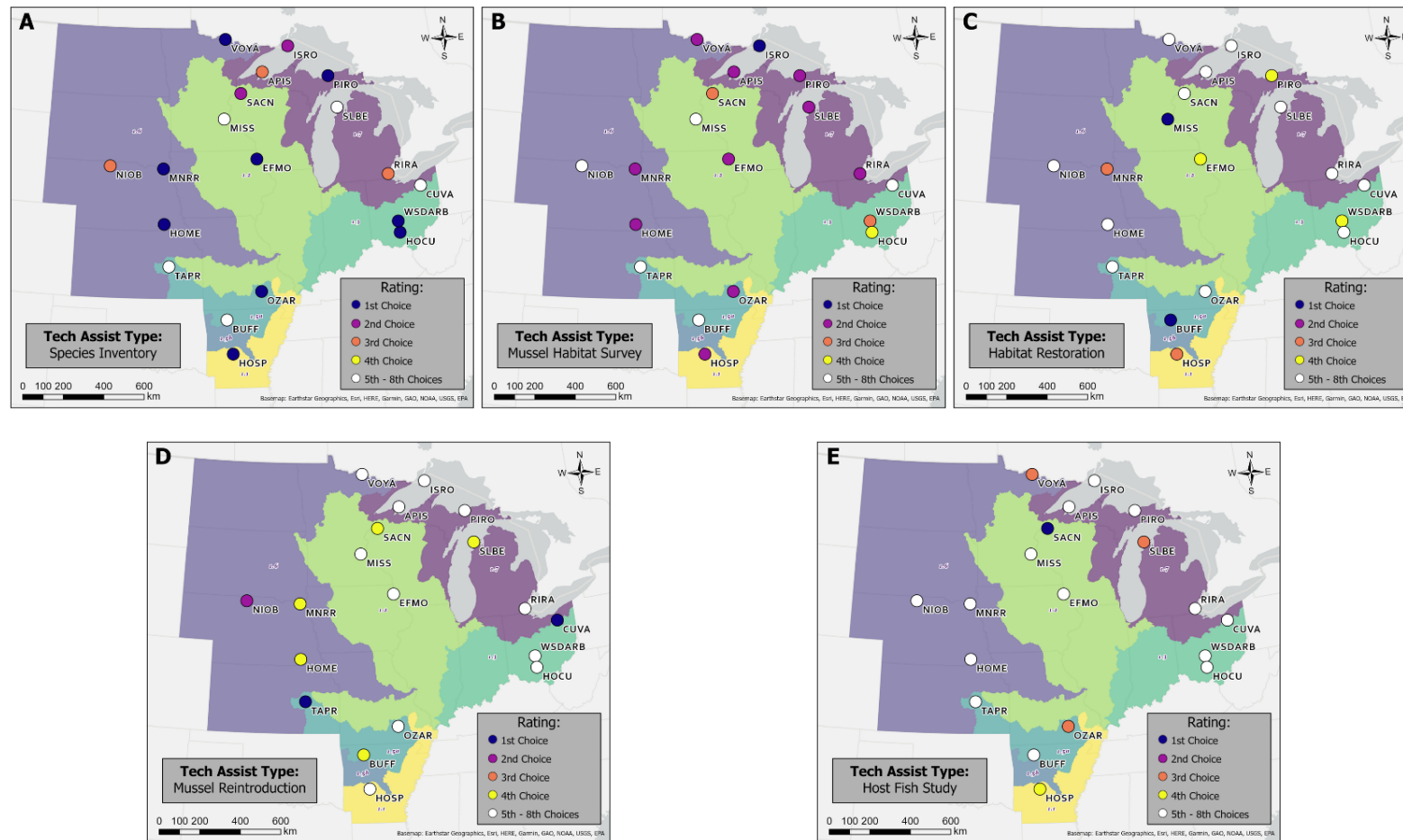


Figure 11. Panel maps of the ratings assigned by park units to the most commonly requested forms of technical assistance offered to them by the MWR. Each panel indicates the ratings for a different type of technical assistance: (A) native mussel species inventories, (B) native mussel habitat surveys, (C) habitat restoration work, (D) native mussel reintroduction, (E) host fish studies, (F) development of interpretation and education outreach materials. For all panels, the color-coding of the point features is the same and indicated in the associated key. The background shading is based on the mussel fauna provinces defined by Haag (2010) and identified in the Figure 1 key.

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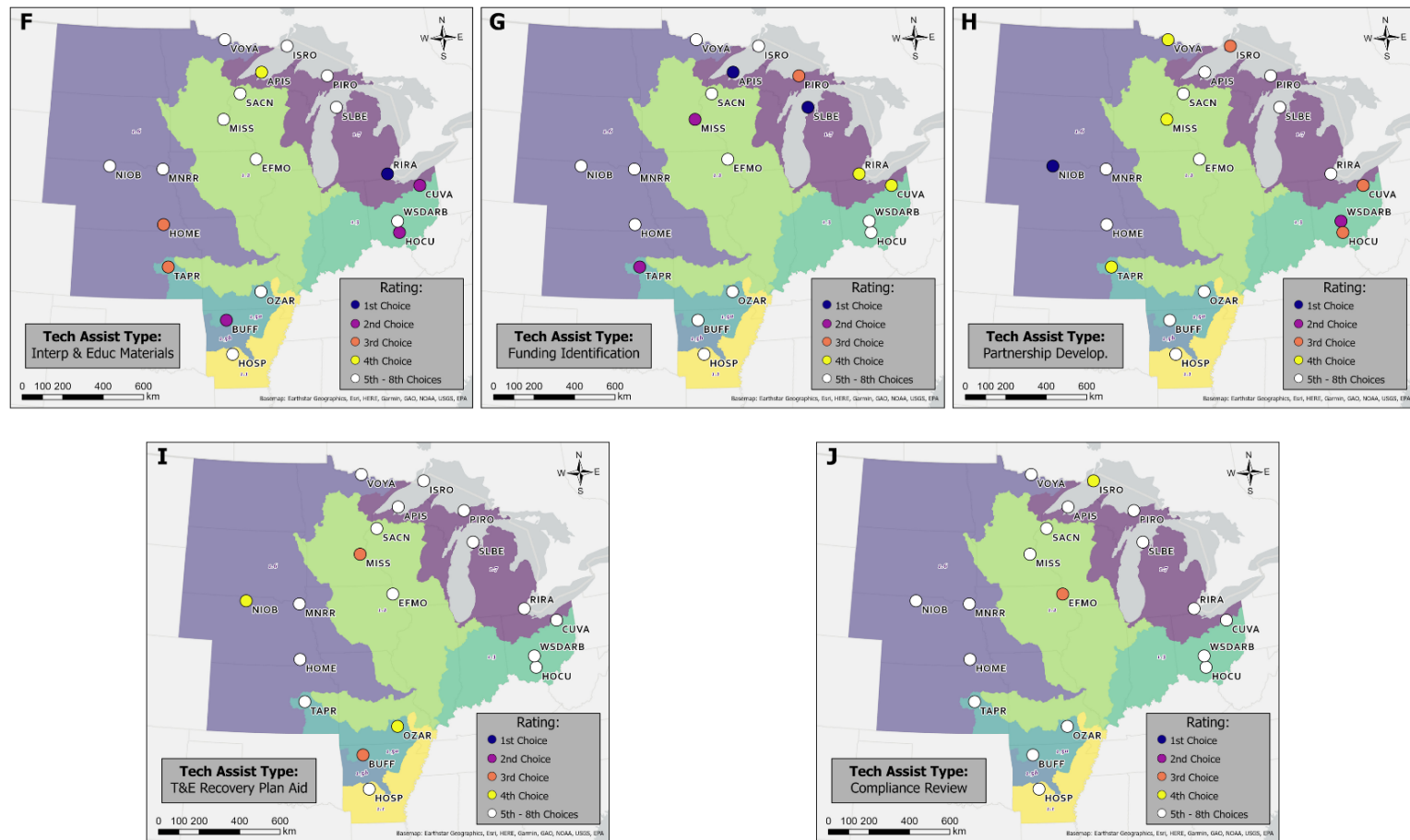


Figure 12. Panel maps of the ratings assigned by park units to the less commonly requested forms of technical assistance offered to them by the MWR. Each panel indicates the ratings for a different type of technical assistance: (G) identification of funding opportunities and development of proposals, (H) development of partnerships with local management agencies or research institutions, (I) assistance with T&E mussel recovery plans and management strategies, and (J) review of compliance documents from a native mussel perspective. For all panels, the color-coding of the point features is the same and indicated in the associated key. The background shading is based on the mussel fauna provinces defined by Haag (2010) and identified in the Figure 1 key.

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Appendix C: Follow-Up Webinar Poll Question Results

Poll questions posed to participants during the follow-up webinar on 7 February 2024 are shown in Figures 13–15.

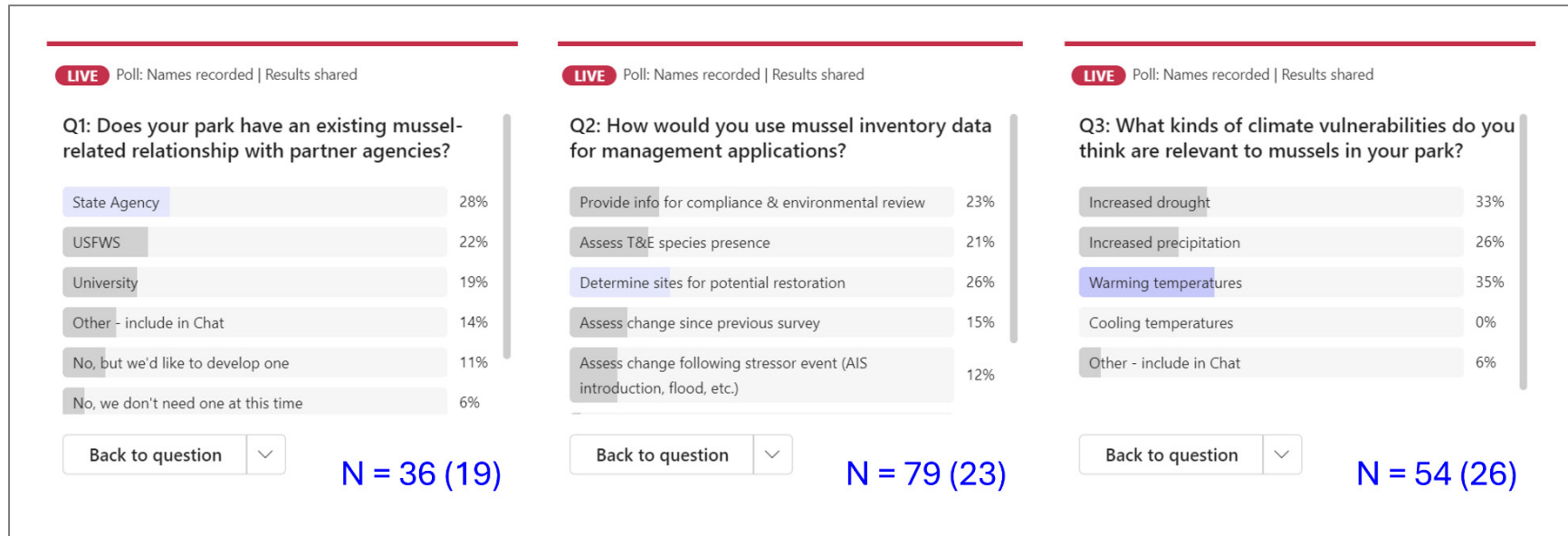


Figure 13. Screenshot showing summary of responses to questions one through three of real-time polls administered to participants during the follow-up webinar on 7 February 2024. The number of responses logged for each question is shown in blue typeface in the bottom right corner of each panel. The number of participants who responded is included parenthetically.

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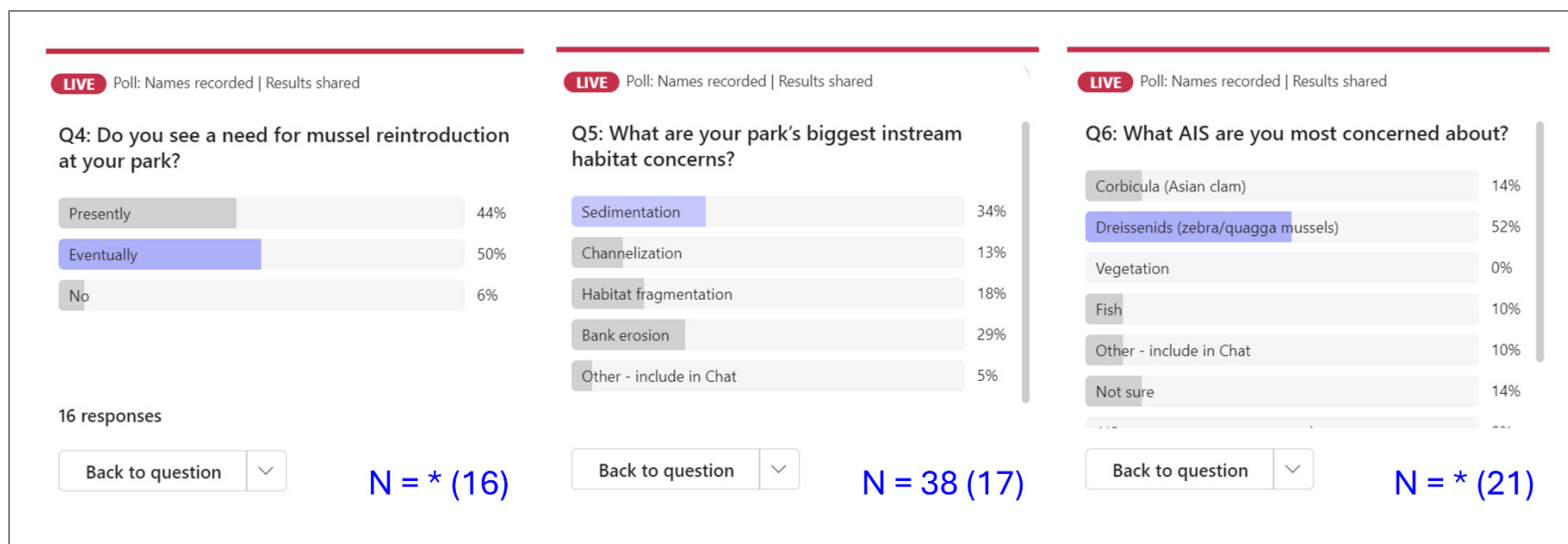


Figure 14. Screenshot showing summary of responses to questions four through six of real-time polls administered to participants during the follow-up webinar on 7 February 2024. The number of responses logged for each question is shown in blue typeface in the bottom right corner of each panel. The number of participants who responded is included parenthetically. For questions that only allowed a single response to be selected, an asterisk is shown instead of the number of responses logged.

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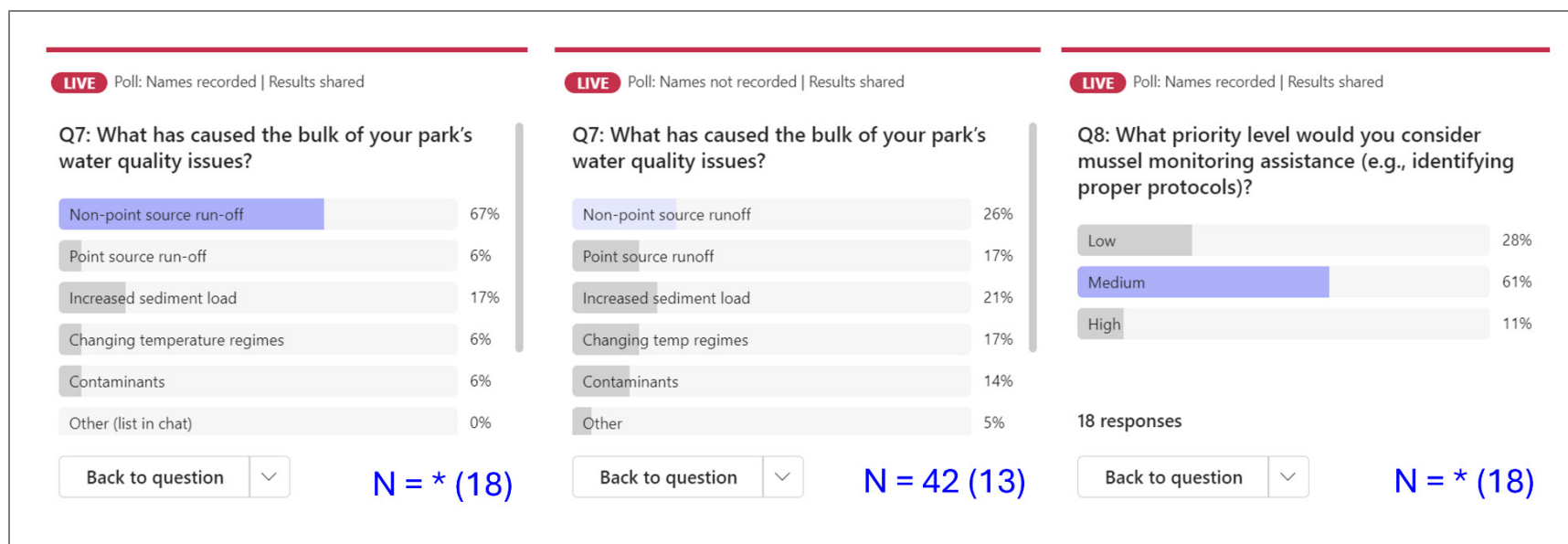


Figure 15. Screenshot showing summary of responses to questions seven and eight of real-time polls administered to participants during the follow-up webinar on 7 February 2024. The number of responses logged for each question is shown in blue typeface in the bottom right corner of each panel. The number of participants who responded is included parenthetically. For questions that only allowed a single response to be selected, an asterisk is shown instead of the number of responses logged. Question seven was posed twice because the first time the settings mistakenly only allowed for a single response; the second time allowed participants to select multiple responses.

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Appendix D: Description of Supplementary Materials

Spreadsheet 1: Joganic-Lafrancois_SuppMat01_Malacologists.xlsx

Provides a database of 55 researchers, federal employees, and contract ecologists who have conducted mussel inventory and survey work or who are experts in freshwater malacology taxonomy. The state where the individual primarily works is provided (Column A), although many have conducted research elsewhere. In a few instances, information on the states in which individuals are licensed to perform survey work is indicated. The contact information that was current as of January 2024 is included. Acronyms (Column D) that are not already defined in the main body of this report are as follows:

- CFWRU: Cooperative Fish and Wildlife Research Unit (USGS)
- EESC: Eastern Ecological Science Center (USGS)
- ESFO: Ecological Services Field Office (USFWS)
- IGLR: Institute for Great Lakes Research (Central Michigan University)
- LGL FWCO: Lower Great Lakes Fish and Wildlife Conservation Office (USFWS)
- NFH: National Fish Hatchery (USFWS)
- USACE: U.S. Army Corps of Engineers
- USFS: United States Forest Service
- WARC: Wetland and Aquatic Research Center (USGS)

Spreadsheet 2: Joganic-Lafrancois_SuppMat02_PropagationFacilities.xlsx

Provides a database of 24 facilities that actively propagate various freshwater mussel species native to North America. Contact and facility information is current as of January 2024. To the best of our ability, we included the species propagated at each facility, but facilities may not readily advertise online all the species with which they work. These resources were compiled from Patterson et al. (2018), the Freshwater Mollusk Conservation Society website (https://molluskconservation.org/MServices_propagation-database.html), and our own Google searches.

Word Document 1: Joganic-Lafrancois_SuppMat03_Bibliography.docx

Provides a list of published articles, books, and reports related to various aspects of freshwater mussel biology, ecology, and conservation. The purpose of this document is to assist resource managers who are less familiar with freshwater mussels gain an understanding of the work that has been done previously to study and conserve them. Sources are subdivided by topic to aid in navigation and alphabetized within each category grouping. Hyperlinks have been provided where available. All others should be accessible online.

Word Document 2: Joganic-Lafrancois_SuppMat04_DecisionSupportTool.docx

Provides a detailed flowchart illustrating a sequence of actions that can be taken to support native mussel conservation projects. Most actions are supplemented in an accompanying table with additional information specifying resources or further explanation of each step. The purpose of this flow chart is to synthesize common conservation activities in a single, easily referenced format that assists resource managers with developing and initiating habitat and mussel population restoration projects. The chart was developed in consultation with the published literature, current practitioners, and subject matter experts.

National Park Service
U.S. Department of the Interior



Science Report NPS/SR—2026/376
<https://doi.org/10.36967/2316514>

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1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525