M.L. 2017 Projects

MN Laws 2017, Chapter 96, Section 2 (beginning July 1, 2017)

Visit the LCCMR website for the most up-to-date project information and reports

Subd. 03 Foundational Natural Resource Data and Information

Subd. 03a County Geologic Atlases – Continuation - $2,000,000 TF (FY2017)

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Appropriation Language
$2,000,000 in fiscal year 2017 is from the trust fund to the Board of Regents of the University of Minnesota, Minnesota Geological Survey, to continue acceleration of the production of county geologic atlases for the purpose of sustainable management of surface water and groundwater resources. This appropriation is to complete Part A of county geologic atlases, which focuses on the properties and distribution of earth materials in order to define aquifer boundaries and the connection of aquifers to the land surface and surface water resources. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Geologic atlases provide maps and databases essential for management of water resources. Of the 16 county atlases covered by this grant, 5 are complete and 6 are past the halfway mark.

OVERALL PROJECT OUTCOME AND RESULTS
The grant funds have been completely expended. This grant funded work in 16 counties including: Lake and St. Louis ($583,175), Kandiyohi ($225,315), Hennepin ($117,254), Hubbard ($100,206), Aitkin ($227,156), Isanti ($37,780), Cass ($110,692), Rock and Nobles ($261,732), Steele ($60,389), Pennington ($27,824), Lac Qui Parle ($53,801), Lincoln and Pipestone ($18,167), and Otter Tail ($106,227) counties. An additional $36,000 supported initiation of work in new project areas and $34,277 was spent to characterize glacial sediments using geochemistry. Atlases for Kandiyohi, Hennepin, Hubbard, Isanti, and Cass are complete. At this time bedrock and surficial mapping in Lake and St. Louis counties is about 75% complete. Good progress has been made on associated databases. Federal cost-sharing has been applied to this work each year. Effort on Olmsted and Dodge counties have been shifted to another funding source, and both should be complete by the end of the summer. In Aitkin County, the bedrock map is nearly ready for review; the bedrock topography is about 75% complete. The Aitkin surficial map is nearly complete, and work on the cross sections and sand models is underway. For the Rock and Nobles CGAs the bedrock maps are about 85% complete and the bedrock topography is nearly ready for review. The surficial geology for both counties is complete, and the work on the cross sections and sand

models is underway. Similarly, in Steele County all bedrock and surficial maps are near completion and work on the cross sections and sand models is underway. The work in Pennington, Lac Qui Parle, Lincoln and Pipestone, and Ottertail counties is still in the early stages with mostly field work underway to support maps. We will conduct rotary sonic drilling in all of these counties (underlined) starting this fall. Counties that are not yet complete have been shifted to the LCCMR18 contract funding.

PROJECT RESULTS USE AND DISSEMINATION
Completed atlas products have been posted to the MGS website and linked to the University's Digital Conservancy as noted above. PDF products as well as all of the related GIS data are available on these pages.

In addition, the MGS hosts an Open Data Portal on which many of our county geologic atlases are presented as "Story Maps" that allow for direct access of the data without any special software or interface.

The Hennepin County workshop was held on April 22 at the County Library in Ridgedale. An article about the atlas and related workshop was published by the SWNewsMedia. Formal presentations for Cass and Hubbard counties were held on March 6 in Backus and Park Rapids, respectively. An update to the Cass County Board was held last summer and written up by the Echo Journal.

Project Completed: 6/30/2020
FINAL REPORT

Subd. 03b Assessment of Public Benefits of Protecting Source Water - $320,000 TF (FY2018)

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Appropriation Language
$320,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to map and quantify source water risks, determine ecosystem service valuation of clean water, and provide analyses of equity and community capacity to improve decisions about the protection and management of groundwater and surface water. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Source Water protection is associated with multiple economic, environmental, and social benefits. We created new spatially-explicit datasets representing multiple socio-economic benefits of source water protection for all 821 drinking water management units in Minnesota. Our work gives practitioners a more complete picture of the outcomes of source water protection statewide.

OVERALL PROJECT OUTCOME AND RESULTS

The goal of the project was to collect and synthesize economic, social, and environmental data relevant to source water protection in Minnesota. We created new spatially-explicit datasets representing multiple socio-economic benefits of source water protection for all drinking water supply management areas in Minnesota. Project outcomes include:

1. Mapping land use change and land protection costs for all 821 drinking water management areas.
    - Estimated trends in land use change in each DWSMA in order to identify potential threats to source water from increasing agricultural expansion or development.
    - Obtained new spatial data based on estimated market values of hundreds of thousands of parcels in the state in order to quantify the opportunity costs of source water protection in each DWSMA.
2. Valuation of the multiple public benefits of land protection for clean water.
    - Applied best-available estimates for drinking water treatment to calculate potential costs of contamination in each DWSMA as a function of population served.
    - Implemented a methodology for estimating the potential health damages and associated monetary costs of drinking water contamination.
    - Generated 19 spatially-explicit environmental benefit maps that can be used to assess the potential for co-benefits of protection or restoration in each DWSMA.
3. Assessing the equity implications of source water protection and community capacity to protect land and improve water quality.
    - Developed a technique for linking source water protection areas to municipalities served, allowing us to relate census data and demographic characteristics to each DWSMA.
    - Administered and analyzed data from a statewide survey of water values in order to identify perceived threats to water quality and preferences for different water-quality related values and uses.
    - Completed a series of participatory water valuation exercises using a Q-sort methodology to understand stakeholder preferences for water-related expenditures and tradeoffs among water quality objectives.

PROJECT RESULTS USE AND DISSEMINATION

We presented our work at venues targeting academic and state agency audiences, and held meetings with specialists at MDH and the interagency GRAPS team exploring application of the work in MN agency work. We shared findings with state agencies including MPCA, MDH, DNR, and BWSR, along with external stakeholders and advocacy groups such as Freshwater Society and the Environmental Working Group. Our work contributed to multiple students' master's theses and is being written up for publication in a peer-reviewed journal. Our work is summarized in a report (available on our website) and includes appendices with data useful for further analysis.

Project Completed: 6/30/2021

FINAL REPORT

Minnesota Water Values

Assessment of Public Benefits of Protecting Source Water

Communicating Risk and Increasing Civic Engagement in Water Protection in Minnesota

Nature in the Urban Century

Source Water Protection Challenges and Co-Benefits

Subd. 03c Preserving Minnesota Prairie Plant Diversity - Phase II – Research Project - $900,000 TF (FY2018)

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Appropriation Language
$900,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to continue collecting and preserving germplasm of plants throughout Minnesota's prairie region, study the microbial effects that promote plant health, analyze local adaptation, and evaluate the adaptive capacity of prairie plant populations. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
We gathered seeds of prairie plants and shared them with producers who are expanding seed availability for restorations. We collected, identified and studied many microbes that prairie plants harbor, documenting their effects on their hosts. Our experiments have clarified the geographic scale of plant adaptation and genetics underlying ongoing adaptation.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesota prairies harbor extraordinary diversity of plants and microbes, while also nurturing wildlife, retaining water and topsoil, and beautifying landscapes. Yet habitat loss threatens the persistence of the once vast prairies and their stunning biotic diversity. Limited understanding of this diversity and insufficient seed availability hinder sustainable management of this iconic Minnesota biome. We conducted Healthy Prairies (HP) Phase II to expand availability of seeds for prairie restorations and study approaches to increase success of restorations. Building on our prior accomplishments under ENRTF funding, we have:

1. Preserved diverse seed from 57 rarer prairie species, gathering them from widely separated locations.
2. Obtained, archived, and studied 2,600 naturally occurring microbial partners from two species.
3. Gathered data to assess the geographic scale important to plant survival and reproduction in MN.

Our extensive collections of source-identified seeds and microbes across a wide range of MN's prairie region help to conserve the diversity of MN prairies. We have provided seeds to seed producers, who have, in turn, used them in establishing fields and are seeking certification of the seeds that they obtain from them.

Our studies of effects of microbial associates on prairie plants have indicated that the bacteria providing

nitrogen to prairie clover (Dalea purpurea, D. candida) disperse widely across MN prairies. Consequently, we can recommend to growers an inoculum that need not be site-specific. In contrast, the communities of fungi associated with roots of S. scoparium are spatially restricted, indicating that a regionally-based inoculum may be preferable.

We continued our large-scale experiment to elucidate the geographic scale of adaptation of six prairie species. We gathered extensive data from this experiment and began analyses of the data. We implemented experiments to investigate genetic structure of two populations of little bluestem (Schizachyrium scoparium), including genetic variance for fitness and the fitness consequences of inbreeding and of crossing between populations.

PROJECT RESULTS USE AND DISSEMINATION
HP team members have participated in varied opportunities to disseminate findings from this project. These include informal events to communicate with members of the public who are not all well-versed in science and may not be aware of prairies (Market Science), as well as workshops involving other scientists and land managers (Nature Conservancy 'Science Slams', Local Adaptation Workshop, held at UM-TC, March 2019, discussions of seed sourcing guidelines led by staff of MN DNR).

A paper providing an overview of the Local Adaptation Workshop has been published in New Phytologist (2020) 225:2246–2248. A manuscript reporting findings about geographic scale of local adaptation has been submitted to Restoration Ecology and has received positive reviews. A second manuscript reporting on a study that used focus groups to identify impediments to use of source-identified seeds for prairie restorations has been submitted to Restoration Ecology and has received positive reviews. Both manuscripts are under revision and will be resubmitted soon.

Project Completed: 6/30/2021
FINAL REPORT
Latitude of Seed Source Impacts Flowering Phenology and Fitness in Translocated Plant Populations
Factors Limiting the Availability of Native Seed for Reconstructing Minnesota's Prairies: Stakeholder Perspectives
Evolutionary Approaches to Seed Sourcing for Grassland Restorations

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Subd. 03d Minnesota Biological Survey – Continuation - $2,900,000 TF (FY2018)

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Appropriation Language
$2,900,000 the first year is from the trust fund to the commissioner of natural resources for continuation of the Minnesota biological survey to provide a foundation for conserving biological diversity by systematically collecting, interpreting, monitoring, and delivering data on plant and animal

distribution and ecology, native plant communities, and functional landscapes. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

The Minnesota Biological Survey (MBS) collects, interprets and delivers foundational data on native plants, animals, plant communities and functional landscapes. These data help prioritize actions to conserve, manage and restore Minnesota's biological diversity and ecological systems.

OVERALL PROJECT OUTCOME AND RESULTS

MBS baseline terrestrial plant field surveys occurred in Lake of the Woods, St. Louis and Koochiching counties within the Border Lakes, Littlefork-Vermilion Uplands, and Agassiz Lowlands subsections. MBS baseline aquatic lake plant surveys occurred in lakes in central Minnesota counties. Plant surveys documented numerous rare and notable terrestrial and aquatic vascular plant species. Native plant community surveys occurred in areas that are either representative of the native vegetation in these counties and subsections or are rare, unique or unusual for these areas. MBS field surveys were also targeted in other northern Minnesota counties to address questions stemming from GIS mapping of native plant communities and sites of biodiversity significance.

Pollinator surveys in MBS sites of biodiversity significance focused on native and rare moths and butterflies in far northern, northwest, and southeast Minnesota. Over 3,000 specimens of at least 900 species were collected, some of which have potential to be new state records.

Targeted surveys occurred in southeast, east-central, and northern forests in MBS sites of biodiversity significance to update and expand MBS data from surveys that occurred in the 1990s and early 2000s. Likewise, similar surveys occurred in the Prairie Province to document new sites or expand on previous MBS surveys from the 1980s. This work resulted in the documentation of many new and updated records of rare species and high quality native plant communities.

Updates and improvements to the DNR Rare Species Guide continued that rely heavily on MBS data and technical expertise arising from this a previous MBS ENRTF appropriations. The book, Sedges and Rushes of Minnesota, was published by the MN Press and the final manuscript for the book, Minnesota Red River Valley and Aspen Parkland - A Guide to Native Plant Communities, was submitted to the UMN Press for publishing.

PROJECT RESULTS USE AND DISSEMINATION

MBS data are stored in the DNR's Natural Heritage Information System and biological specimens accessioned to the UMN Bell Museum of Natural History. This includes information on rare species, native plant communities, sites of biodiversity significance. MBS distributes survey results on the MBS website, DNR GIS QuickLayers, and MN Geospatial Commons. Presentations, technical guidance, biological reports, and published books are delivered that describe and interpret MBS results for use by local government units, conservation groups, citizen advisory groups, scientists, land managers, and students. MBS data, products, and staff expertise are used throughout the state to assist conservation decisions.

Project Completed: 6/30/2021

FINAL REPORT

Subd. 03f Assessment of Microbes for Improving Wild Rice Restoration – Research Project - $334,000 TF (FY2018)

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Appropriation Language
$334,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Natural Resources Research Institute, to evaluate the microbial communities and nutrients associated with wild rice and competing vegetation, with the goal of enhancing restoration success to increase the abundance of wild rice. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The project improved our understanding of microbial and nutrient associations with self-sustaining wild rice wetlands. This information will be useful to develop management strategies for wild rice restoration success, which will improve long-term protection of native species and aquatic biodiversity, and support management of Minnesota's culturally and ecologically important natural resource.

OVERALL PROJECT OUTCOME AND RESULTS
Wild rice (Zizania palustris), a native emergent aquatic plant, has a multitude of ecological functions and high cultural and economic value in Minnesota. Wild rice was historically abundant in northern Minnesota but its abundance and distribution have been reduced due to various factors. There have been collaborative efforts to restore wild rice wetlands for improved wildlife habitat and increased opportunities for wild rice harvest. Despite ongoing efforts, restoration has been met with mixed success. Much research was conducted on surface water and sediment chemistry that is conducive to wild rice growth. However, one ecological component of the wild rice ecosystem that remains under-explored is microbial communities that are involved in processing key nutrients. This project characterized microbial communities associated with wild rice wetland. Wild rice and coexisting plant samples were collected from 7 wild rice wetlands along with water and sediment. High-throughput DNA sequencing analyses indicated that wild rice-associated microbial communities were distinct from those found in water and sediment. Moreover, the influence of surface/porewater chemistry and nutrients on the microbial communities were evaluated. The project outcomes will allow the restoration partners to understand why restoration efforts are successful or not and can be immediately transferable to restoration managers for the development of applicable restoration practices. Likewise, if beneficial microbial groups associated with self-sustainable wild rice beds were identified from this project, the methods to encourage their abundance and functions for wild rice growth are needed through seeding with inoculants derived from successful wild rice stands and sediment amendments. If coexisting or invasive species alter nutrients and microbial community structure unfavorable for wild rice fitness by imposing some degree of selective pressures, targeted species control is essential prior to current

restoration efforts. This will be useful to for the partners to develop effective management strategies for wild restoration goals.

PROJECT RESULTS USE AND DISSEMINATION
The project findings have been disseminated via reports to LCCMR, publications, and regional and national presentations at conferences. We held four meetings with wild rice managers and the project partners for field sampling plan, project progress, consultation and outcomes. The project findings were shared with the public through the university's news article, public outreach activities (e.g. Lake Superior Youth Symposium), and student stories. Moreover, microbial DNA sequences of environmental samples collected from wild rice wetlands were archived at National Center for Biotechnology Information.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03i Landslide Susceptibility, Mapping, and Management Tools - $500,000 TF (FY2018)

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Appropriation Language
$500,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to create landslide susceptibility maps using a landslide inventory and quantitative analysis of LiDAR to provide tools and data for mitigation and restoration to reduce impacts on water resources. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Landslides in five regions across Minnesota were mapped and inventoried to identify geologic and topographic conditions vulnerable to slope failures providing resource and emergency managers with better predictive tools to guide land-use decisions. Landslides are a dominant source of sediment to regional waterways, occurring frequently along steep valley walls.

OVERALL PROJECT OUTCOME AND RESULTS
In June 2014, widespread landslides occurred in south-central Minnesota; a similarly rainy period in 2012 caused two deaths. In June 2012, a two-day rain event in Duluth generated hundreds of landslides, extensively damaging Jay Cooke State Park and surrounding areas. In August 2007, a year's worth of rain fell in 36 hours in southeastern Minnesota causing extensive landsliding. Weak clay soils in the Red River valley frequently fail, undermining homes and roads. All of these eroding, hazardous slopes present an acute natural resource and emergency management challenge, yet until now, the state lacked landslide hazard maps. Because mass wasting processes vary with geology, we defined five study areas in which we documented the distribution, failure mechanisms, and frequency of landslides in order to help resource managers make sound mitigation decisions.

Each region was mapped by a different partner institution using established data standards and protocols through: 1) historical research, 2) mapping known slides onto high-resolution lidar base maps, and 3) identifying additional landslides using lidar data; topographically-derived maps (slope, hillshade, and red relief); and aerial imagery. Slide sites were field-checked where possible for geology, hydrogeology, vegetation cover, and land use.

In northeastern Minnesota, where repeat lidar data were available, additional work was done. Repeat lidar data collected before and after a major 2012 storm event were properly aligned to allow erosion and deposition to be quantified, and Object-Based Image Analysis was used to define and classify types of change (erosion, deposition in different settings) across the landscape.

Landslide susceptibility modeling in that same, well documented area illuminated which landscape parameters were most important to slope stability: slope, distance to stream, and depth of glacial deposits overlying competent bedrock. The method developed in northeastern Minnesota can be applied to the other four areas of the state.

PROJECT RESULTS USE AND DISSEMINATION
Project results were disseminated to local and regional stakeholders through presentations at meetings and to the scientific community through conference presentations. The full inventory database is being released through the U. S. Geological Survey with an accompanying U. S. Geological Survey Fact Sheet on Landslides in Minnesota. These products will be available to assist with emergency management planning and natural resource assessments of sediment loading in watersheds across the state. Details on landslide mapping methodologies and results across the state, and multitemporal lidar correction and Object-Based Image Analysis research in northeastern Minnesota will be published through publicly-available scientific papers.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03k Cedar Creek Natural Area Wolf Recolonization Assessment – Research Project - $398,000 TF (FY2018)

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Appropriation Language
$398,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Cedar Creek Ecosystem Science Reserve, to assess wolf recolonization impacts on wildlife, biodiversity, and natural resources and provide educational opportunities at Cedar Creek Ecosystem Science Reserve.

This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Minnesota's wolves are expanding southward. A new pack recently recolonized Cedar Creek Ecosystem Science Reserve, which is one of the best-studied ecosystems worldwide. Our project assessed costs (e.g., unwanted impacts on pets and livestock) and benefits (e.g., impacts on biodiversity and ecosystem functioning, educational opportunities) of this unassisted wolf recolonization.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesota's wolves (Canis lupus) are expanding southward. A new pack recently became established at Cedar Creek Ecosystem Science Reserve (henceforth Cedar Creek), which is one of the best-studied ecosystems worldwide, located just north of the Twin Cities. The goals of our project were to assess costs (e.g., unwanted impacts on pets or livestock) and benefits (e.g., potential enhancement of biodiversity and ecosystem functioning, educational opportunities) of this unassisted wolf recolonization. Our project achieved the following outcomes: (1) determine wolf movements inside and nearby Cedar Creek; (2) experimentally test the impacts of wolves on wildlife, biodiversity, and ecosystem functioning; and (3) provide educational programming to K-12 students and adults. We achieved these goals and outcomes by establishing a network of trail cameras, establishing a new experiment to assess wolf impacts on plants and soils, and bringing K-12 students to Cedar Creek for field trips and developing a website for engagement by citizen scientists. We found that wolf pack produced three litters of pups and grew to include up to 19 wolves, but was then lethally removed by federal trappers after preying on livestock and dogs (Mech et al. 2019). We also found that wolf cues shifted when, but not where, deer used the landscape (Palmer et al. 2021). Deer used risky areas at relatively safe times of the day, when wolves are typically less active, attenuating any cascading effects of wolves on plants or soils. Our Eyes on the Wild citizen science website has thus far engaged 12,625 registered citizen scientists who have provided 7,636,071 classifications of 4,153,218 images generated by our network of trail cameras. These data are being included in several national and global studies of wildlife (e.g., Suraci et al. 2021). More than 7,000 K-12 students and adults engaged in programming related to the project.

PROJECT RESULTS USE AND DISSEMINATION
Project results have been widely disseminated. The Eyes on the Wild website has engaged 12,625 registered users (and thousands more non-registered users), who provided 7,636,071 classifications of 4,153,218 images from our cameras. Project information and results have been widely shared through in-person and online lectures, K-12 school programs and field trips, summer camps, community events, art shows, educational curricula, and local workshops which reached more than 7,000 community members over the lifetime of the project. Additionally, the project has generated four scientific publications, and regular coverage by local print, radio and television outlets.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03l Effects of Wolves Predation on Beaver, Moose, and Deer – Research Project - $293,000 TF (FY2018)

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Appropriation Language
$293,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Voyageurs National Park to assess the effects of wolf predation on beaver, moose, and deer in the Border Lakes region. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Our studies of how, where, and when wolves prey on beavers, moose, and white-tailed deer shed exciting new light on the interactions of these iconic denizens of Voyageurs National Park, Minnesota's only National Park.

OVERALL PROJECT OUTCOME AND RESULTS
Gray wolves are widely known to prey on adults and fawns/calves of white-tailed deer and moose. Beavers also make up a large portion of wolf diet in areas where beavers are plentiful. Scientists have long pondered how the abundance of beaver prey can affect wolf predation on moose and deer. Voyageurs National Park - Minnesota's only National Park – and the surrounding area offers the perfect natural laboratory to learn about wolf hunting behavior and how that affects deer and moose in an area of high beaver densities, as densities can be 2-10x higher here than anywhere else in the state. We captured and GPS-collared 42 wolves in at least 12 different wolf packs to follow their movements and find sites where they killed their prey during the spring-summer-fall period. We identified >1,045 kills, including kills of 335 beavers, 192 adult and 444 fawn white-tailed deer, 1 adult and 1 calf moose, and 65 kills of ≥12 other species including snowshoe hare, bears, muskrats, raccoons, swans, geese, ducks, and other birds. Some of our key findings include understanding how wolf predation can affect beaver abundance, pond creation, and even water storage; better understand how wolves use ambushing behavior and cooperative hunting techniques to hunt and kill beavers; how wolves use roads and trails and areas of recent timber harvest to target and kill deer fawns; and how wolves use a variety of other food sources such as fish and berries to persist in an environment where food can often be scarce. While issues surrounding management of wolves, deer, and moose tend to generate a variety of opinions, better understanding the summer ecology of wolves, especially in a relatively pristine environment such as in Voyageurs National Park, can only improve the ability for Minnesotans to better co-exist with wolves and their prey.

PROJECT RESULTS USE AND DISSEMINATION
This collaboration between Voyageurs National Park and the University of Minnesota produced 15 scientific papers and other reports. Our findings have influenced the understanding of wolf behavior and the importance of beavers to forested landscapes in the U.S. and beyond. Research about charismatic species like wolves, beavers, moose, and deer are often very interesting to the general public. We capitalized on that interest by engaging the public through several social media outlets, most notably

through a popular Facebook page created by the University of Minnesota. Check out the University of Minnesota's Voyageurs Wolf Project website for project information.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03m Mapping Taxonomy and Environmental Toxicology of Minnesota Freshwater Sponges – Research Project - $258,000 TF (FY2018)

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Appropriation Language
258,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Crookston, to determine freshwater sponge distribution, identify and quantify accumulated contaminants, and provide educational research opportunities to undergraduate students. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Our project identified freshwater sponges are widely distributed throughout Minnesota's lakes and rivers. Sponges are thought to be bio-indicators of good water quality, suggesting many rivers and lakes in Minnesota are of relatively good quality. We identified new species of freshwater sponges not described previously, so there is likely significant amounts of biological diversity not described in the state. As filter feeders, it doesn't appear that freshwater sponges are accumulating pollutants that can be passed through the food chain.

OVERALL PROJECT OUTCOME AND RESULTS
Freshwater sponges are the simplest animals and play a vital role in the aquatic ecosystem by functioning as a filter feeder and providing habitat and nutrients for other aquatic life. As filter feeders, freshwater sponges could potentially accumulate pollutants and transfer them through the food chain to game fish and other economically important aquatic and terrestrial organisms. Furthermore, despite their importance, information on the distribution of freshwater sponges in Minnesota lakes and rivers is very limited. The primary goals of this project were to **(1) determine the diversity and distribution of freshwater sponges in Minnesota's water basins and watersheds and to (2) determine if these freshwater sponges are accumulating toxic pollutants.**

From our sampling of freshwater sponges, we found freshwater sponges are widely distributed throughout the state of Minnesota. We sampled over one hundred locations and found freshwater sponges at over 75% of the locations sampled, resulting in a total of 169 individual freshwater sponges collected. The majority of the freshwater sponges collected are species that have previously been identified in the state. We identified one new species of freshwater sponge from this project, while

potentially identifying a few more after additional follow-up analyses.

From the chemical analysis of collected sponges there does not appear to be an accumulation of pollutants within the sponge that could be passed through the food chain. Our chemical analysis did identify interesting and unique chemical compounds in the freshwater sponges that has the potential for having bioactivity and could be used for human purposes.

The results of this project showed that freshwater sponges are widely distributed in the state of Minnesota, supporting the notion that these animals are important for the freshwater ecosystem. We have identified new species of freshwater sponges, and importantly, it doesn't appear that sponges are accumulating pollutants that could remain in the ecosystem. We were also able to train 18 undergraduate students in biological and chemical research. Many of these students have gone on to be scientists, nurses, doctors and other important jobs in Minnesota.

PROJECT RESULTS USE AND DISSEMINATION
The dissemination of the project has occurred through multiple mediums. This project was highlighted in the Minnesota DNR's Minnesota Conservation Volunteer Magazine. The project has also been shared with the general public by being added to the Minnesota State Parks and Trails Geocaching Aquatic Quest. An important aspect of this project was providing research opportunities for our undergraduate students at the University of Minnesota Crookston. The research involvement by students was highlighted in a number of publications. This results of this project were also presented at multiple scientific and non-scientific conferences by faculty and students.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 04 Water Resources

Subd. 04a Assessment of Household Chemicals and Herbicides in Rivers and Lakes – Research Project - $236,000 TF (FY2018)

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Appropriation Language
$236,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to quantify environmental levels of household chemical and herbicide ingredients in rivers and lakes and assess their potential to form toxic by-products.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The levels of quaternary ammonium compounds (QACs), which are used widely as disinfectants and for

other purposes, were measured in Minnesota wastewaters and sediments. The QACs are present at microgram per liter levels in wastewater. While the QACs are slowly degraded in surface waters by bacteria and light, they accumulate in sediments. The QACs form specific suspected carcinogens during water disinfection in very low yield, and QACs are likely less important than other precursors for these toxins. The results provide information on current QAC levels and provide insights on how to lower them if desired.

OVERALL PROJECT OUTCOME AND RESULTS

Quaternary ammonium compound (QACs) are ingredients in personal care products, fabric softeners, disinfectants, and herbicides. QACs, which are biologically active molecules, are unintentionally and intentionally released into the environment. QACs kill bacteria and may affect microbial communities in wastewater treatment and algal communities in surface waters. In this study, the levels of QACs in the effluent from 12 wastewater treatment plants were determined. Plants with more advanced treatment processes had lower levels of QACs. Sediment samples in a lake demonstrated potential inputs from both municipal wastewater effluent and agricultural sources for QACs. In sediment cores taken from lakes, two distinct trends over time were observed. In lakes with large watersheds and mixed domestic and industrial wastewater sources, peak concentrations of QACs were found at depths corresponding to deposition in the 1980s and decreases after this time are attributed to improved wastewater treatment and source control. In a smaller lake with predominantly domestic wastewater inputs, concentrations of QACs increased slowly over time. In surface waters, QACs were found to degrade by reaction with reactive species (hydroxyl radicals) generated by sunlight and by microbial processes. Even with these loss processes, QACs likely persist from days to weeks in the water, leading to their deposition in the sediments. QACs were found to form low levels of a carcinogenic class of compounds (nitrosamines) when reacted with a drinking water disinfectant (chloramine), but this would be of greatest concern in wastewater potable reuse scenarios. The overall results of the work indicate that QACs are being released by wastewater treatment plants. Once in the environment, degradation by bacteria and by sunlight can occur in surface waters, but accumulation in sediments, where the QACs are persistent, is likely the main removal process. During the wastewater disinfection process QACs can form a carcinogen, but QACs are not as important as other chemicals known to form nitrosamines. The findings allow more robust assessment of potential impacts of QACs and insight into wastewater treatment processes that lead to removal, which is important given the increasing use of QACs during the COVID-19 pandemic.

PROJECT RESULTS USE AND DISSEMINATION

Three papers were published: 1) the detection of QACs in wastewater and sediment (the paper and data set are available online); 2) Photolysis of QACs; and 3) Potential environmental impacts of elevated QAC usage during the COVID-19 pandemic (available online through ACS Publications or PubMed Central). A public lecture that incorporated data for the project was also given at the U of MN, and it is available on YouTube.

Project Completed: 6/30/2019
FINAL REPORT

Subd. 04b Wastewater Nitrogen Removal Technology to Protect Water Quality – Research Project - $450,000 TF (FY2018)

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Appropriation Language
$450,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to develop a technology for inexpensive low-energy nitrogen removal in wastewater. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
A group of bacteria ("anammox") have received attention for their potential in wastewater treatment, transforming harmful reactive nitrogen into harmless dinitrogen gas. However, anammox perform poorly in typical wastewater environments. In this project we developed new materials to selectively enhance anammox growth/retention, supporting more sustainable removal of harmful nitrogen.

OVERALL PROJECT OUTCOME AND RESULTS
Anammox bacteria have received attention for their ability to completely transform harmful reactive nitrogen compounds in wastewater into harmless dinitrogen gas. In addition, when using anammox bacteria, much less oxygen and no supplemental carbon is needed for nitrogen removal, and there is little production of excess biomass in the form of sludge. This reduces costs and energy use for nitrogen removal. It is estimated that the anammox process saves 60% of the energy used in conventional nitrogen removal. Unfortunately, this process has been difficult to implement in typical wastewater systems. Anammox bacteria are slow growing and the ammonium and carbon concentrations in wastewater result in low anammox activity and competition from faster growing bacteria. This leads to the washout of anammox bacteria. In this collaborative research project, our goals were to develop new polymeric materials that could concentrate ammonium to create localized niches for anammox enrichment and retention. We developed two different materials in this project: (1) a porous polymer carrier and (2) a gas-permeable alumina membrane. Both materials were able to concentrate ammonium, while the membrane could also transfer low quantities of oxygen to the surrounding solution. Both materials were also able to enrich and retain anammox when added to a wastewater environment. Further optimization of these materials is needed to enable scale-up and deployment. Nevertheless, given that in the US, the energy used for wastewater treatment costs approximately $2B a year, the predicted energy savings if this technology was implemented would be significant. The impact within the state of Minnesota would also be large, saving millions of dollars and providing more complete removal of harmful nitrogen species. A patent was awarded and the University of Minnesota is exploring commercialization and licensing options. Three peer-reviewed manuscripts were published from this work and have been submitted to the LCCMR.

PROJECT RESULTS USE AND DISSEMINATION
Information from this project has been shared with several water technology companies who may be able to assist in optimizing and eventually deploying this technology. As stated above, three peer-

reviewed manuscripts were published from this work and have been submitted to the LCCMR. Multiple presentations about the research have been given to both regional and national/international conferences. Additional funding is being sought from a large infrastructure company. We anticipate submitting a proposal to the National Science Foundation for additional funding. The University of Minnesota Technology Commercialization Office is working with us to further the technology.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 04c Rearing Native Mussels for Reintroduction and Expanding Water Quality Awareness - $591,000 TF (FY2018)

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Appropriation Language
$591,000 the first year is from the trust fund to the Minnesota Zoological Garden in cooperation with the Department of Natural Resources to accelerate the reintroduction of native mussels into Minnesota rivers and streams through expanded mussel rearing, research, and statewide educational activities promoting mussel conservation and water quality. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The Minnesota Zoo increased capacity for rearing mussels to more than 10,000 individuals and researched methods to improve husbandry, enabling us to better support efforts to recover depleted populations. The Show Us Your Mussels challenge engaged >2,200 students, with student-created content reaching >150,000 citizens and encouraging action to benefit conservation.

OVERALL PROJECT OUTCOME AND RESULTS
Native mussels are aquatic engineers, providing important ecosystem services such as water filtration and creating habitat for fish and other wildlife. However, many populations are depleted in Minnesota due to factors such as overharvest and pollution. With this project, the Minnesota Zoo sought to support state-wide recovery efforts led by the DNR and improve mussel conservation by 1) increasing our capacity to rear juvenile mussels for reintroduction; 2) advancing our understanding of mussel husbandry to improve the growth and survival of individuals in our care; and 3) raising public awareness about and encouraging action to benefit our aquatic resources.

We constructed a new mussel rearing and research facility on the Zoo's campus and installed associated systems for housing mussels. These improvements significantly increased our capacity for rearing mussels; we currently have space to accommodate >65,000 newly transformed mussels, surpassing our

target of 10,000 individuals. This expansion significantly increases our conservation impact and positions us to better support ongoing recovery efforts that will restore ecosystem services.

We also conducted experiments to evaluate how substrate affects growth and survival of juvenile mussels. Our research documented that the presence of fine sand in rearing pans significantly increases growth rates for some species. As such, we have modified our husbandry methods to incorporate this finding, which will yield larger individuals more suitable for reintroduction and ultimately may accelerate reintroduction efforts.

To encourage local communities to take action on behalf of water quality, we established the Show US Your Mussel Challenge. This project engages middle and high school students in the creation of social media campaigns to expand communications efforts throughout local communities. To date, >2,200 students have participated in the challenge, sharing information about the importance of mussels, Minnesota's aquatic resources, and actions the public can take to protect Minnesota's waterways with >150,000 residents.

PROJECT RESULTS USE AND DISSEMINATION
Communicating the importance of native mussels and water quality was a key goal of this project. The Minnesota Zoo engaged with Minnesotans to share information about mussels, their conservation, and stewardship of aquatic resources via a variety of platforms, ranging from in-person and virtual presentations at schools, camps, and other forums to free school curriculum and teacher professional development in association with the Show Us Your Mussels challenge. We developed an interpretive area on Zoo campus, outfitted with signs, videos, and a water quality activity, shared research findings at scientific meetings and hosted Smart Salt workshops to reduce salt use.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 04d Water Quality Monitoring in Southeastern Minnesota Trout Streams - $500,000 TF (FY2018)

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Appropriation Language
$500,000 the first year is from the trust fund to the Board of Trustees of Minnesota State Colleges and Universities, Winona State University, to develop a system of biological monitoring for water quality protection of trout streams in southeastern Minnesota. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Strobin fungicides were detected in most water samples from the Whitewater River in southeastern Minnesota. Many citizen scientists were trained and continue to monitor stream sites. Stream habitats and fish and aquatic invertebrate communities ranged from excellent to poor, based largely on upstream versus downstream location and adjacent land uses.

OVERALL PROJECT OUTCOME AND RESULTS
Water quality in many trout streams in southeastern Minnnesota has been compromised by rain-event runoff, exposing sensitive trout to mixtures of eroded soils, pesticides, urban stormwaters/wastewaters, and animal wastes. The main goal of this project was to better protect at-risk streams by developing an improved water-quality monitoring infrastructure and network within the Whitewater River system. This was achieved by:

- Automated Water Sampling - establishing both continuous and rain-event sampling throughout 3 at-risk trout stream reaches (North, South, Middle Forks of the Whitewater River),
- Citizen Scientists - training an action network of citizen scientists to respond to episodic run-off events and to monitor water quality and aquatic life in these and additional trout stream reaches, and
- Baseline Surveys - conducting inclusive biotic inventories of fish and aquatic invertebrate communities throughout entire at-risk watersheds for broader, complete delineation of baseline conditions.

Water sampling detected various strobin fungicides in >80% of rain event and low-flow samples, with some concentrations above toxic levels for aquatic life. Strobin concentrations were higher in rain-event samples, but concentrations could not be predicted by rain volume or season. Increased monitoring and better chemical management are needed in these and other watersheds to protect our coldwater ecosystems.

More than 30 citizen scientists have been trained to monitor stream water quality and aquatic invertebrate communities with the Whitewater River and nearby stream systems. They assess their chosen stream sites four times per year, and upload their findings directly to the Izaak Walton League's Save Our Streams web portal. In addition to regular seasonal monitoring, citizen scientists can respond to sudden events (e.g., floods, fish kills) to gather additional information as needed.

Based on surveys at 62 sites, stream habitats and biotic communities ranged from excellent to poor, influenced largely by upstream/downstream location, adjacent land uses, and proximity of springs.

PROJECT RESULTS USE AND DISSEMINATION
Results from our project were the basis for two MS theses completed at Winona State University, and a chapter of a PhD dissertation completed at the University of Minnesota. At least two papers reporting our findings will be published in the peer-reviewed scientific literature.

Our 30+ trained citizen scientists have reported and will continue to report their stream monitoring data to the Izaak Walton League's Save Our Streams web portal, where they are continually available to the public.

Project results also have been reported to the scientific community at seven different state, regional, and national science meetings.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 04e Reassessing Toxicity of Petroleum Spills on Ground and Surface Water – Research Project - $300,000 TF (FY2018)

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Appropriation Language
$300,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the University of St. Thomas to reassess long-term effects of oil spills through the analysis of chemical parameters related to oil degradation and evaluate the impacts on aquatic species, groundwater, and surface waters. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The groundwaters contaminated with chemicals from the decades-old crude oil spill and/or their breakdown products can adversely affect development and hormone and liver functioning if vertebrates were to be exposed to them sufficiently. This project advanced understanding of oil spill remediation and will help protect Minnesota's natural resources/drinking water sources.

OVERALL PROJECT OUTCOME AND RESULTS
A fundamental issue in protecting ecosystem health in Minnesota is the degree to which waters impacted by, relatively common, petroleum releases (e.g., oil or gasoline spills) are toxic, both initially and over time as the oil breaks down into new chemicals. This study was the first to comprehensively screen the toxicity of groundwater from an aged crude oil spill site. The National Crude Oil Spill Fate and Natural Attenuation Research Site near Bemidji, MN is the site of a 1979 pipeline rupture that released 10,000 barrels of crude oil. This site has been extensively studied for over 40 years offering a unique opportunity to study the toxicity of groundwaters impacted by crude oil. Groundwater samples (collected 2016-2019) were analyzed for over 90 different chemical and toxicity parameters using cutting-edge techniques where living cells were exposed to water samples and screened for potential toxic effects. Analysis of the molecular/toxicity targets that were activated in cells indicated that (even 40+ years after the spill) the groundwaters contaminated with chemicals from the original spill and/or chemicals resulting from the breakdown of the oil compounds have the potential to cause adverse impacts on development, endocrine, and liver functioning if vertebrates (fish, turtles, birds, mammals) were to be exposed to them sufficiently. This work clearly shows the need to improve understanding of the identity and toxicity of oil breakdown products. Furthermore, this work shows that commonly used

sampling and analysis methods (including sample extraction and clean-up protocols) can exclude or under-represent oil breakdown products and thus may underestimate risks from these chemicals. This finding is of importance to remediation managers and regulators in Minnesota and nationally because there is an active debate as to which methods and protocols are most suitable for hazard and risk assessment at petroleum spill sites.

PROJECT RESULTS USE AND DISSEMINATION
We published three research manuscripts, presented at numerous research conferences, and raised awareness of the issue with Minnesotans statewide (reached circa 1200 individuals at the State Fair exhibits). We introduced oil industry, and managers and regulators in MN and nationally to a new toolbox of novel cell and artificial intelligence approaches that can streamline hazard assessment and facilitate identification of chemicals/hazards of concern and enhance oil spill remediation monitoring. Results of our work are relevant to Minnesotans as the analyses conducted herein advance an understanding of oil spill remediation and will help protect Minnesota's natural resources/drinking water sources.

Project Completed: 6/30/2021
FINAL REPORT
Toxicity Assessment of Groundwater Contaminated by Petroleum Hydrocarbons at a Well-Characterized, Aged, Crude Oil Release Site - 7 pgs
Biological Effects of Hydrocarbon Degradation Intermediates: Is the Total Petroleum Hydrocarbon Analytical Method Adequate for Risk Assessment? - 9 pgs

Subd. 05 Environmental Education

Subd. 05a Connecting Youth to Minnesota Waterways through Outdoor Classrooms - $1,200,000 TF (FY2018)

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Appropriation Language
$1,200,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Wilderness Inquiry to provide place-based environmental education science water experiences to approximately 20,000 middle- and high-school students. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The Floating Classroom served more than 25,000 Minnesota youth by creating opportunities to engage in environmental science through accessing Minnesota waterways and public lands. Youth assessed

natural resources, collected scientific data, developed a stewardship ethic, and learned about outdoor employment opportunities, becoming Minnesota's next generation of natural resource protectors.

OVERALL PROJECT OUTCOME AND RESULTS
All told since the beginning of the project in June 2017, Wilderness Inquiry's Floating Classroom connected more than 25,714 Minnesota youth to environmental science and Minnesota's abundant waterways and public lands.

On live outdoor events, Wilderness Inquiry's Floating Classroom served 24,421 diverse Minnesota youth through placed-based, educational experiences, creating opportunities to engage in environmental science through accessing Minnesota waterways and public lands. Of these youth, 23,600 youth engaged in hands-on exploration, recreation and assessment of said waterways and public lands and 821 youth participated in a multi-day expedition, learning to restore and maintain public lands and discover pathways into outdoor-related employment.

When COVID-19 forced Minnesota schools into distanced learning and limited the gathering of groups, the Floating Classroom quickly pivoted to meet the needs of educators and families educating and learning from home. Wilderness Inquiry's Online Learning Resources were created and this website has been visited by 1,254 unique visitors. Some highlights include pages dedicated to Environmental Science and Natural Resources (visited by 353 visitors) and Jobs in the Outdoors (visited by 126 visitors). The full scope of these resources goes much further with downloadable activities and additional pages being shared among virtual classrooms.

As COVID-19 continued to impact the Floating Classroom's ability for in person programming through summer 2020, Wilderness Inquiry and the National Park Service partnered together to create a free virtual summer camp to connect youth to the mysteries of the Mississippi River. 39 Minnesota Youth took part in this camp focused on the ecology of the Mississippi River.

PROJECT RESULTS USE AND DISSEMINATION
While participating in Floating Classroom activities, students collected water quality data and this data was reported back and disseminated through a citizen science online portal Canoe Quest via GLOBE, a national database for citizen science.

Wilderness Inquiry worked with the University of Minnesota's Center for Applied Research and Educational Improvement (CAREI) to evaluate the project. CAREI produced two reports over the course of the three years which were shared directly with partners and stakeholders, presented at conferences, and can be found on the Wilderness Inquiry website.

Lastly, many local media outlets covered the Floating Classroom's arrival throughout the state. Many of these are included in the Wilderness Inquiry blog, including this story from MPR.

Project Completed: 6/30/2020
FINAL REPORT

Subd. 05b Increasing Diversity in Environmental Careers - $487,000 TF (FY2018)

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Appropriation Language
$487,000 the first year is from the trust fund to the commissioner of natural resources in cooperation with Conservation Corps Minnesota and Iowa to encourage a diversity of students to pursue careers in environment and natural resources through internships and mentorships with the Department of Natural Resources, the Board of Water and Soil Resources, and the Pollution Control Agency. This appropriation is available until June 30, 2022, by which time the project must be completed and final products delivered.

Project due to be completed: 6/30/2022
FINAL Abstract

Subd. 05c Interactive Water Resource Programs for Planetariums Minnesota - $500,000 TF (FY2018)

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Appropriation Language
$500,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Bell Museum of Natural History, to create an interactive planetarium program on water resources, reaching approximately 400,000 citizens statewide through the Bell Museum Planetarium, St. Paul Public Schools, Mayo High School, Mankato East High School, Southwest Minnesota State University, Minnesota State University Moorhead, and University of Minnesota Duluth. This appropriation is available until June 30, 2022, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Water flows out of Minnesota in three directions, and our personal and public choices have impacts far beyond our borders. With Minnesota Water Stories, citizens tour Minnesota in planetariums across the state, to learn about issues in each region and understand what they can do to protect this natural resource.

OVERALL PROJECT OUTCOME AND RESULTS
The planetarium dome is an ideal place to provide an immersive venue for citizens to understand

complex topics such as time, scale, and geographic perspective as they relate to water. The shape of a dome fills our peripheral vision and mirrors the way our eyes see the world around us, which allows the audience to feel they are part of the story, connected to the decisions made by themselves and others. A skilled presenter can tailor the show to the needs of the audience, so each experience is unique. *Minnesota Water Stories* includes a mixture of animation and live-action video from a dozen locations around the state including Park Rapids, Halstad, Breckenridge, Redwood Falls, Waseca, Wabasha, and Tofte.

The outcomes for citizens attending *Minnesota Water Stories* were to increase awareness of challenges facing our waters, understand the challenges' relations to the larger system, and becoming aware of community resources to work toward addressing these problems. Due to the pandemic, we were not able to do a full-scale evaluation of the show in planetariums around the state. We created an online version with similar content as the planetarium show to measure how it meets these outcomes. According to the evaluation report, "general audience and student participants increased their understanding of challenges facing Minnesota waters."

Almost 1,000 Minnesotans saw the interactive and audience participatory experience of *Minnesota Water Stories* in its initial run at the Bell Museum's Whitney and Elizabeth MacMillan Planetarium, and 231 students and public reviewed the web-based version. Over the next few years Minnesota Water Stories will show to thousands of people at planetariums in Baxter, Duluth, Hibbing, Mankato, Marshall, Moorhead, Rochester, St. Cloud, and St. Paul.

PROJECT RESULTS USE AND DISSEMINATION
This project produced a planetarium show and an online StoryMap that all Minnesotans can access. To date, over 900 Minnesotans have seen the show at the Bell Museum. In fall 2022 it will be available for audiences in planetariums in nine cities around the state and can travel to any region with the University of Minnesota's portable planetarium system. In the years to come, thousands of Minnesotans will view *Minnesota Water Stories*.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 05e Local Planning and Implementation Efforts for Bird Habitat - $280,000 TF (FY2018)

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Appropriation Language
$280,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the National Audubon Society, Minnesota office, to engage approximately 60 communities and 400,000 citizens in bird habitat improvement through local planning and implementation efforts using

the National Audubon Bird City program. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Through Bird City Minnesota, Audubon Minnesota has engaged communities in improving the habitat and protecting birds. Nine communities completed the certification program, while many more have been using this conservation roadmap to leverage resources and achieve results in making their communities friendly for birds and wildlife.

OVERALL PROJECT OUTCOME AND RESULTS

Bird City Minnesota has worked to enhance conservation efforts to protect birds and habitats in Minnesota communities. A total of nine communities have received the Bird City Minnesota designation, while many other communities have showed interest and start working to complete the requirements of the program. Bird City Minnesota requirements lead communities in taking steps to accomplishment conservation efforts that improve habitat through restoration, reduce threats to birds, and engage local citizens through projects, training and birding events. Many of the communities that participated made substantial progress in protecting habitat in local parks and engaging citizens in hands-on conservation work that creates a healthier environment for birds. By focusing on these efforts, local communities have engaged their residents in citizen science and conservation. Through public events, residents have learned how to take simple actions that result in improving the landscape for birds and ensuring appropriate habitat.

During the course of this project, the COVID-19 pandemic significantly disrupted the progress that communities were making in attaining Bird City Minnesota recognition. Staff have been flexible to support communities as necessary, made adjustments where appropriate, and encourage continued work towards completing the program event after the funding of this project has ended. Minnesotan's have benefited from this work by learning simple steps that they can take in their own communities to make a difference for birds, and what they have learned in this process will benefit communities and birds for decades to come.

PROJECT RESULTS USE AND DISSEMINATION

While the project was significantly affected by the COVID-19 pandemic, we have been able to successfully promote the achievements of communities through significant local news media coverage for cities who have achieved the Bird City Minnesota recognition. Additionally, signage and flags are now displayed in each of the communities that have completed the Bird City Minnesota requirements and were awarded recognition. Application materials have been shared with communities to assist in their continued fulfillment of program requirements, as well as to serve as historical records of the conservation efforts taken.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 05f Developing Youth Watershed Stewardship in Northwest Minnesota - $121,000 TF (FY2018)

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Appropriation Language
$121,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Headwaters Science Center to accelerate a multiyear environmental science club for middle-school students focused on water quality, watershed evaluation, and aquatic invasive species in northwestern Minnesota. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The project entitled Developing Youth Watershed Stewardship in Northern Minnesota established the Environmental Science Club. Goals were established, pursued and met:
skill development, enhanced understanding, recognition of relationships between actions and outcomes, provided positive experiences, shared similar information through presentations, and demonstrated deeper understanding of ecosystems.

OVERALL PROJECT OUTCOME AND RESULTS
Environmental Science Club was established in early 2019 for 10 to 18 students led by HSC staff in each of 2-hour club sessions. Members came to HSC from two sources: Boys & Girls Club of Bemidji with students from fifth grade to eight grades along with HSC's youth participants. Students explored ground-water, examined rivers & built models of watersheds; culminating with a lakeshore clean-up. The club was expanded into summer where Voyageurs Expeditionary High School students participated in a four-day outdoor ecological study as part of their summer school course curriculum requirements.

Club activities resumed heading into the fall and winter of 2019. Specimens from area water were gathered and examined. Eighteen students participated in Environmental Science Club.

With the turn of the new year, HSC headed into 2020 with twelve more club sessions in January, February, and early March. Then Covid-19 struck & we were soon surrounded by uncertainty with hybrid models for students attending class & afterschool activities virtually. In this phase we co-opted our "Daily Live Science Show" -once a week- with labs testing for chloride & then showing E. coli sampling & lab technique for various local stream studies.

Our hybrid approach shifted again to macroinvertebrate assays, crowd sourced, demonstrating how to gather, sort, classify & count organisms for our pollution intolerance index. With this scale we were able to determine water quality by presence, or lack thereof, pollution intolerant organisms, as well as diversity. This scale allowed us to determine, and present electronically degree of ecological integrity. Despite most environmental news being dire and even depressing, we are pleased to present our

findings of excellent condition for many streams and even found pollution sensitive organisms in places way downstream. We are thankful that this LCCMR grant allowed us to share these insights.

PROJECT RESULTS USE AND DISSEMINATION
Club participants always focused on results -via exploration & the scientific method- utilizing various skills learned for water examination. In the first thirty months of the project, participants presented knowledge they had gained at science fairs & peer-to-peer feedback sessions. Student field journals, notes & posters accompanied project presentations. Final professional production of posters was not completed. Funding for this portion of the project was remains unspent and this portion of the grant should be returned to the ENRTF.

During the last six months of the grant cycle the pandemic overtook us, so we shifted to a hybrid virtual model. Our 3:30 show became a regular afternoon session on three platforms: YouTube, Facebook and Twitch TV with final selected videos appearing on the hscbemidji.org Website.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 06 Aquatic and Terrestrial Invasive Species

Subd. 06a Aquatic Invasive Species Research Center - Phase II – Research Project - $2,700,000 TF (FY2017)

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Appropriation Language
$2,700,000 in fiscal year 2017 is from the trust fund to the Board of Regents of the University of Minnesota to support the Minnesota Aquatic Invasive Species Research Center in finding solutions to Minnesota's aquatic invasive species problems through research, control, prevention, and early detection of existing and emerging aquatic invasive species threats. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

Sub-Projects M.L. 2017, Subd. 06a:

- *4.3: Social Learning and Carp Removal - Przemek Bajer* - $189,475
- *8.2: Impacts of Invader Removal on Native Vegetation Recovery - Daniel Larkin* - $119,034
- *12.2: Historical Analyses of Spiny Water Flea Invasion Patterns - Donn Branstrator* - $53,795
- *15: Determining Highest Risk Vectors of Spiny Water Flea Spread* - Valerie Brady* - $26,581

- *16.2: AIS Impacts on Walleye Populations and Mercury Concentrations - Gretchen Hansen* - $199,862
- *18.2: Genetics to Improve Hybrid and Eurasian Watermilfoil Management - Raymond Newman* - $236,423
- *20: A Novel Technology for eDNA Collection and Concentration* - Abdennour Abbas* - $96,264
- *21.2: Field validation of mulitbeam sonar zebra mussel detection (Year 1)** - Jessica Kozarek* - $14,247
- *22: Copper-Based Control – Zebra Mussel Settlement and Non-Target Impacts* - James Luoma* - $152,090
- *23: Public Values of Aquatic Invasive Species Management* - Amit Pradhananga* - $110,245
- *24: Genetic Method for Control of Invasive Fish Species* - Michael Smanski* - $140,004
- *25: What's in Your Bucket? Quantifying AIS Introduction Risk* - Nicholas Phelps* - $84,094
- *28: Evaluating Innovative Coatings to Suppress Priority AIS - Mikael Elias* - $51,234
- *30: Managing Midwestern Aquatic Invasions in a Changing Climate - Ranjan Muthukrishnan* - $39,000

*Subproject is split between M.L. 2013 and M.L. 2017 funding, only M.L. 2017 funds are reflected.
**Subproject is split between M.L. 2017 and M.L. 2019 funding, only M.L. 2017 funds are reflected.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

This project continued MAISRC's work to develop research-based solutions that can reduce the impacts of aquatic invasive species in Minnesota. Through this appropriation, MAISRC has supported 15 subprojects on many of Minnesota's most important AIS, significantly advanced our scientific understanding and ability to manage AIS and engaged thousands of stakeholders and partners.

OVERALL PROJECT OUTCOME AND RESULTS

The Minnesota Aquatic Invasive Species Research Center (MAISRC) continued to develop research-based solutions that can reduce the impacts of AIS in Minnesota and advance AIS knowledge among natural resources managers, the research community, and the public. In total, 15 subprojects were supported from this project – significantly advancing our scientific understanding and ability to manage AIS. New tools have been developed and knowledge gaps filled on many of Minnesota's most important AIS, including zebra mussels, spiny water flea, bigheaded and common carps, and starry stonewort. The results of this work have been broadly disseminated via research reports, peer-reviewed manuscripts, fact sheets, white papers, news media, newsletters, social media, and direct stakeholder engagement through presentations, workshops/trainings, and public events. Highlights of project outcomes include identifying the highest risk methods of introduction and spread of spiny water flea and baitfish viruses, advancing innovative control tools for established AIS like zebra mussels and common carp, and defining the impact of AIS on ecosystems and sportfish populations. Throughout this project, MAISRC has continued to serve as a global leader in the field of AIS research and a go-to resource for managers, researchers, and members of the public.

This project also supported MAISRC's work to ensure the effectiveness and efficiency of a center-based research model. Progress in this area included an ongoing, comprehensive process for prioritizing research needs; stronger collaboration and coordination between researchers and managers; a competitive, peer-reviewed annual proposal competition; and increased communications and outreach capacity to help managers and community members translate research findings into on-the-ground management.

MAISRC continues to advance Minnesota's resiliency and ability to address AIS issues facing our state through research, collaboration, and stakeholder engagement. This project will continue with Phase II and III appropriations awarded in 2019 and 2021.

PROJECT RESULTS USE AND DISSEMINATION
The MAISRC website has become a resource for AIS stakeholders across the state with an average of 40,000 users visiting the site each year. MAISRC and the AIS Detectors program also have active social media accounts on Twitter, Facebook, and YouTube. MAISRC and AIS Detectors' videos on YouTube, including webinars and project spotlights, have collected nearly 94,000 views, totaling an estimated 2,700 hours of watch time. MAISRC's Twitter account has grown into a popular means of connecting researchers, legislators, community organizations and nonprofits, and other AIS stakeholders. Social media posts continue to disseminate research findings, highlight behind-the-scenes project activities, promote MAISRC events and AIS Detectors workshops, and share invasive species news. In addition, the MAISRC e-newsletter delivers in-depth stories about MAISRC research and management tools to more than 5,300 people and growing.

Project Completed: 06/30/2022
OVERALL FINAL REPORT

Sub-Project 4.3: Social Learning and Carp Removal - $189,475 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
A new method for removing common carp to improve water quality and habitat was developed. It uses bait to attract carp and remove them. It is very selective and easily scalable. While its efficacy is being improved, it is already being used by lake managers in Minnesota.

OVERALL PROJECT OUTCOME AND RESULTS
Common carp is a widespread, invasive fish that negatively impacts habitat and water quality in lakes. Practical and selective removal strategies are needed for carp. Previous research showed that bait can be used to selectively attract large numbers of carp in lakes. In this experiment, we documented how the carp are attracted to the bait (Objective 1; social structure) and whether they could be removed using nets (Objective 2). In a lake with multiple baiting sites (8 sites in a 258-acre lake) and 300 carp tagged with electronic tags, 54% of carp (164 tags) were attracted to the bait over the whole summer, and ~ 20% of population were attracted daily (60 tags). Some carp ("Superfeeders") visited baited sites

nearly every day, while others only every few days. The Superfeeders were significantly larger than other carp. The carp visited the bait mainly at night. Feeding aggregations were very dynamic – individual feeding bouts included 2-9 tagged carp, lasted <1 minute to over 30 min, and continuously formed and dissolved for several hours each night. We attempted three removal events at the baited sites, on 3 separate nights, collectively capturing 27% of the population (3,602 carp). Native fish bycatch was <1% (released).

Our results indicated that carp foraging is social, easily induced by species-specific bait, dominated by large-bodied individuals, and predictable (nightly). However, only a fraction of carp attracted to the bait were removed because individual feeding groups visited that bait at different times of the night. We suggest that next steps should address how to synchronize carp aggregations at the bait to increase removal efficiency (starts in January 2022 using acoustic conditioning). This line of research resulted in carp removal methods that are already being applied in Minnesota, often involving volunteers to bait the carp. Future optimizations will increase the efficacy of this new management method.

PROJECT RESULTS USE AND DISSEMINATION

To disseminate the results of this work we have presented two talks at scientific conferences focusing on invasive species and lake management:

Bajer P. G. et al. 2019. A new approach to manage common carp: Citizen-aided carp management. International Conference on Aquatic Invasive Species ICAIS, Montreal, Canada.

Hundt, P. J., Bajer P. G. 2020. Common Carp Feeding Aggregations: Responses of Invasive Carp and Native Fish to Corn Baiting, North American Lake Management Society, Minneapolis, MN.

We have published two peer-reviewed manuscripts:

Hundt, P. J., Amberg, J., Sauey, B., Vacura, K., & Bajer, P. G. (2020). Data from: Tests in a semi-natural environment suggest that bait and switch strategy could be used to control invasive Common Carp. Management of Biological Invasions.

Hundt PJ, While LA, Craft ME, Bajer PG. In review. Social associations in common carp: Insights from induced feeding aggregations for targeted management strategies. Ecology and Evolution.

We were featured in a Star Tribune article from January 30, 2021: Corn, Conveyor Belts and a Virus show promise in removing invasive carp from Minnesota Waters. We were also featured in a Minnesota Bound episode on common carp management in Lake Parley https://www.youtube.com/watch?v=3sS-Ej3VU4w.

We have also presented twice at the MAISRC Research & Management Showcase and conducted a webinar on common carp management that included 150 participants from several states. https://youtu.be/zNXcB1IfhqM.

Subproject 4.3 Completed: 06/30/2021

FINAL ABSTRACT

FINAL Graphic

Sub-Project 8.2: Impacts of Invader Removal on Native Vegetation Recovery - $119,034 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project adds to the growing understanding that invasive species are often only one of multiple stressors that drive declines in the health of our lakes. Controlling invasive plants is not a silver bullet for restoring turbid, degraded lakes—we have to think more holistically about what's dragging down our lakes' health.

OVERALL PROJECT OUTCOME AND RESULTS
Controlling dominant invasive aquatic plants is a common goal of many stakeholders around the state. These invader-reduction efforts are often motivated as ways to promote the health or recovery of native plant communities—but the potential for these efforts to actually meet those goals is uncertain. We hypothesized that, in addition to potential competitive effects of invasive species, insufficient water clarity and native plant recolonization can also be "rate-limiting" components of restoring lake vegetation. If so, these limitations must be addressed and invader control alone will be inadequate for restoration. We addressed this issue in two ways: (1) By evaluating responses of native plants to actual, on-the-ground management efforts in invaded lakes in MN through synthesis and analysis of monitoring data. This can tell us how management is working across the state at scales relevant to lake managers. (2) We compared those conclusions to results of field experiments designed to untangle how invaders, light limitation, and reproduction can hinder native plant recovery. Overall, our work resulted in the aggregation of more than 4,000 surveys that will be used to evaluate responses of native plants to curlyleaf pondweed, Eurasian watermilfoil, and the management of each of these AIS. The funding supported the completion of all experimental fieldwork, bringing four years of work to a conclusion. In short, our experiments and data synthesis reveal that native plant recovery following invader control is a realistic outcome—but only under certain conditions, i.e., where water clarity and propagule availability are sufficient to foster native plant recovery. In addition, our results show that Eurasian watermilfoil exerts a stronger negative effect on native plants than curlyleaf pondweed. Thus, control of Eurasian watermilfoil is more likely to foster native recovery than is control of curlyleaf pondweed. If lake management is to restore native macrophytes, it must target the factors that are limiting native species recovery, and we show that invasive species are one of multiple limiting factors in Minnesota lakes.

PROJECT RESULTS USE AND DISSEMINATION
This project has produced materials of interest to a wide variety of stakeholders covering a wide breadth of the work the project entailed. Among these products are peer-reviewed publications, videos, presentations, posters, databases, and a data dashboard. Videos include a webinar on the statewide plant survey database, an instructional video describing point-intercept and delineation plant-survey

methods for student and extension audiences, and two short presentations—one describing analysis of statewide data for management evaluation, and another describing ecological work using statewide data to define the niches of macrophytes. A poster and a presentation detail much of the work that went into developing aquatic plant revegetation methods. The statewide database is available as a database and through a beta-version dashboard. Multiple publications will detail the work as it pertains to contributions to the state of knowledge on the ecology and management of aquatic plants. All of these materials are available upon request.

Peer-reviewed publications:

Verhoeven, M. R., D. J. Larkin, and R. M. Newman. (2020). Constraining invader dominance: Effects of repeated herbicidal management and environmental factors on curlyleaf pondweed dynamics in 50 Minnesota lakes. Freshwater Biology, 65(5), 849–862. https://doi.org/10.1111/fwb.13468

Verhoeven, M. R., W. J. Glisson, and D. J. Larkin. (2020). Niche models differentiate potential impacts of two aquatic invasive plant species on native macrophytes. Diversity, 12, 162. https://doi.org/10.3390/d12040162

Published datasets and R code:

Verhoeven, M. R., D. J. Larkin, and R. M. Newman. (2020). Complete data and analysis for: Constraining invader dominance: Effects of repeated herbicidal management and environmental factors on curlyleaf pondweed dynamics in 50 Minnesota lakes. Data Repository for the University of Minnesota. https://doi.org/10.13020/aw92-e606

Verhoeven, M. R., W. J. Glisson, and D. J. Larkin. (2021). Complete data and analysis for: Niche models differentiate potential impacts of two aquatic invasive plant species on native macrophytes. Data Repository for the University of Minnesota. https://doi.org/10.13020/cwqe-ge69

Subproject 8.2 Completed: 06/30/2021
FINAL ABSTRACT
FINAL Graphic

Sub-Project 12.2: Historical Analyses of Spiny Water Flea Invasion Patterns - $53,795 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
After spiny water flea was first recorded in North America in the 1980s, sediment core analysis was heralded as a method to document the timing of lake invasions with implications for understanding and

managing spread and threats. Our study casts concern on the method, revealing limitations to pinpoint early detection.

OVERALL PROJECT OUTCOME AND RESULTS

Spiny water fleas threaten Minnesota's lakes, including walleye health, but we do not understand how many years it takes for the threats to manifest once they invade. This project was a continuation of Subproject 12 where we sought to use evidence in lake sediments to determine the timeline of first presence and growth of spiny water fleas in Lake Kabetogama and Lake Mille Lacs. The results of Subproject 12 demonstrated that spiny water fleas have been present in both lakes continuously since the early 1900s. This timeline conflicts with data on first sightings that do not place spiny water fleas in either lake until the early 2000s. This gap of about 100 years suggests that our sediment analysis methods are biased. With Subproject 12.2, our main objective was to conduct two additional lines of inquiry to determine the suitability of our methods by 1) measuring natural rates of mixing in surface sediments of Lake Kabetogama and Lake Mille Lacs, and 2) searching sediment cores that were collected before first sightings of spiny water fleas in Lake Kabetogama. The results demonstrate that 1) natural rates of sediment mixing are not sufficient to explain the early presence of spiny water flea body remains in Lake Kabetogama or Lake Mille Lacs sediments, and 2) there is no evidence in historical core material that places spiny water fleas in Lake Kabetogama before their reported year of first detection in the water. We combined our results with results from scientists at Queen's University (Canada) who have recently used similar methods to ask similar questions, into a forthcoming publication in the Journal of Paleolimnology. In that publication we review our findings and caution the use of our methods to pinpoint early detection of spiny water fleas in lakes until further study of the methods is conducted.

PROJECT RESULTS USE AND DISSEMINATION

We widely disseminated the results of Phase I of Subproject 12 (M.L. 2013) but we have not thus far disseminated any of the results in Phase II for two reasons. First, the COVID pandemic limited our opportunities. Second, the controversial nature of our results led to a hesitancy among us to share them until we had fully analyzed all evidence and lines of inquiry, both in our data set and the data set contributed by our collaborating scientists at Queen's University. Peer-reviewed publications are in process and presentations on results will be given as a part of the MAISRC Showcase.

Subproject 12.2 Completed: 06/30/2021
FINAL ABSTRACT
FINAL Graphic

Sub-Project 15: Determining Highest Risk Vectors of Spiny Water Flea Spread - ML2013 $92,932/ ML2017 $26,581 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Spiny water fleas are an invasive zooplankton that threaten Minnesota lakes. In tests of recreational fishing gear, fishing lines entangled the most spiny water fleas and should be the focus of cleaning efforts. In addition, all water should be removed from bait buckets and livewells to prevent spreading this invader.

OVERALL PROJECT OUTCOME AND RESULTS

Spiny water fleas are a predatory non-native zooplankton that threatens the ecology and recreational value of Minnesota lakes. Estimates are that >40% of northern Minnesota lakes are vulnerable to invasion. These invaders are primarily spread by human recreational activity, but we do not know exactly how this is happening. Our project goals were to 1) determine which types of recreational fishing gear would entangle (and thus spread) spiny water fleas, and 2) widely disseminate our results and gear-cleaning tips. We conducted 7 sampling events on Lake Mille Lacs, collecting 718 samples including zooplankton tows and spiny water flea counts on fishing gear and anchor ropes. We found that fishing lines accumulated the most spiny water fleas and thus should be the focus of angler cleaning efforts. In addition, it is critically important that all water be removed from bait buckets and livewells to prevent spread. To help recreational anglers clean their fishing gear, we printed and/or coordinated the distribution of over 20,000 cellulose dish cloths that were printed with cleaning instructions. 8,000 cloths were printed and distributed to 18 community partners (lake associations, AIS prevention staff, agency partners) as a part of this project and an additional 12,000 were printed and distributed through coordination with partner organizations and additional funders. Cloths were distributed to recreational anglers, focusing on those who move between spiny water flea infested lakes and uninfested lakes. In addition, we launched the stopspiny.org website to disseminate research findings and share prevention resources and created three PSA videos that demonstrated how to use the cloth to clean fishing lines. The videos played on YouTube, Facebook, Twitter, and TV in the Lake Superior, Lake of the Woods, Mille Lacs, Twin Cities markets. Facebook advertising was used to extend the stop spiny PSAs, reaching over 208,000 individual people and resulting in 442,000 impressions. PSA ads were also placed in local, online and print publications with an estimated reach of 103,000 readers. The research team also wrote one scientific manuscript and presented their results 19 times to about 1,500 people.

PROJECT RESULTS USE AND DISSEMINATION

All outreach was done with strong collaboration and support from MAISRC staff.

Stop Spiny Cloths: To help recreational anglers clean their fishing gear, we printed a simple image of a spiny water flea and what they look like when ensnared on fishing lines, along with cleaning instructions and funder logos, on 8,000 cellulose dish cloths. These cloths look like a steam-rolled sponge. Use of these cloths (or any cloth) to wipe fishing line prior to leaving an infested lake will help prevent the spread of spiny water flea from lake to lake. In testing, we found that these cloths are easy to use to clean fishing lines (and a more useful product than our original idea of a sticker). These cloths were distributed this spring to about 18 partners (lake associations, AIS spread prevention staff, agency partners, etc.). In addition, we facilitated the Minnesota Lakes and Rivers Advocates to help about 25 other groups (mostly lake associations and conservation districts) order over 9,000 more spiny wipe cloths for distribution. In total, we have or are in the process of facilitating distribution of over 20,000 cloths (3,000 of these were part of our companion project funded by St. Louis County) to wipe spiny water fleas from angler fishing lines.

To support distribution of the cloths and assist those distributing them, MAISRC staff worked with us to create an outreach campaign that we called the "Stop Spiny" campaign.

Website: The Stop Spiny campaign was chiefly hosted on the MAISRC website at stopspiny.org, which redirects to www.maisrc.umn.edu/stopspiny. The web page was created in Fall 2020 by MAISRC staff. Since its creation, the Stop Spiny campaign page has been viewed over 4,721 times. The average time a visitor spends on the page is nearly two minutes and thirty seconds. The Stop Spiny campaign webpage, as of Jan. 2022, is the seventh most popular page on the entire MAISRC website over the last year and a half.

The Stop Spiny campaign page gives an overview of spiny water flea invasion history and impacts and explains how water recreationists can help prevent the spread of spiny water fleas. A video about the project results is linked on this page. Additional information includes an interactive map showing current spiny water flea invaded lakes in Minnesota and links to additional spiny water flea research and species pages.

MAISRC staff also created a Stop Spiny campaign resources web page. This page hosts a variety of Stop Spiny factsheets, images, videos, fliers, and more for the free use and distribution of educators, resource managers, lakeshore associations, and/or any others hoping to help prevent the spread of spiny water fleas. The average time spent on this page by users was six minutes, which is very long by web page viewing standards and indicates that visitors are taking the time to read and download the information on this webpage.

Videos: To help share the Stop Spiny message in a visually interesting format, we worked with MAISRC and UMD to produce multiple high-quality videos. Three different video lengths were created—15 seconds, 30 seconds, and a full length (~2:30 min). The videos were shared on multiple social channels, including MAISRC's Facebook and Twitter accounts. The videos were also used in different combinations for Facebook advertisements and a television advertisement. On YouTube alone, the videos have accumulated over 850 views.

Advertisements: The Stop Spiny campaign included a combination of digital and print advertising. Print advertising included placements in the Lake Country Journal (based near the spiny water flea-infested Lake Mille Lacs), the Ely Summer Times (distributed along the Minnesota Iron Range, in the heart of spiny water flea-infested lakes), and Northern Wilds Magazine (another Northern Minnesota distributor). The estimated reach, per outlet, as provided by their respective company websites are as follows; Lake Country Journal—40,000; Ely Summer Times—28,000; Northern Wilds Magazine—18,000.

Northern Wilds Magazine, which also has an online edition and active online community, was contracted for Stop Spiny banner ads. The ads were placed on the Northern Wilds Magazine website at the top column of their side bar. The company estimates that their web pages see roughly 17,000 page views per month. Stop Spiny advertisements were placed on the top side bar for three consecutive months, from June to August 2021.

In addition, extensive Facebook advertising was used to enhance the Stop Spiny campaign. Multiple rounds of advertisements were planned to coincide with time of year and spiny water flea population increases. Since the launch of the campaign in spring 2021, Stop Spiny advertisements on Facebook reached over 208,000 individual people and resulted in 442,000 impressions. Included in all the advertisements were hyperlinks to the Stop Spiny campaign website for additional information and

resources. In total, over 1,500 people clicked from the advertisement to the Stop Spiny campaign page.

On average the amount of time an individual person will watch a video on Facebook is six seconds. Engaging users to watch more than six seconds is a huge engagement success. By the end of the Stop Spiny campaign, over 29,000 users watched the Stop Spiny video they were served to completion (15-30 seconds) and over 60,000 users watched over 50% of the video they were served (7-15 seconds).

Finally, we have had numerous radio and print articles about our project and how to stop the spread of this invasive species, including an outreach article by MAISRC personnel in a Minnesota angling magazine (Activity 2, Outcome 4). Additional outreach has included working with Lake Minnetonka local government staff to use their lighted electronic boards to promote Stop Spiny messages, creating Stop Spiny factsheets and handouts, and sidebar online advertisements on the Northern Wilds website. Our Stop Spiny website hosts all these videos, factsheets, an interactive map, the radio scripts, and presentations for watercraft inspectors. The PIs published one scientific manuscript, and gave 19 presentations to over 1,500 people in total.

Peer-Reviewed Publications

• Donn K. Branstrator, Joshua D. Dumke, Valerie J. Brady & Holly A. Wellard Kelly (2021): Lines snag spines! A field test of recreational angling gear ensnarement of Bythotrephes, Lake and Reservoir Management, DOI: 10.1080/10402381.2021.1941447

Presentation Recordings/Videos

• 2021 MAISRC Research & Management Showcase Presentation
https://z.umn.edu/2021ShowcaseSpiny
• 2020 MAISRC Research & Management Showcase Presentation
https://z.umn.edu/2020ShowcaseSpiny
• AIS Detectors Webinar: Lines Snag Spines! Preventing the Spread of Spiny Water Flea
https://z.umn.edu/DetectorsWebinarLinesSnagSpines
• MAISRC Video: Preventing the Spread of Spiny Water Flea
https://z.umn.edu/MAISRCPreventingSpinySpread

Select Media Coverage

• Minnesota Opinion: Avoid catches you don't want this fishing season – West Central Tribune
https://www.wctrib.com/opinion/editorials/ minnesota-opinion-avoid-catches-you-dont-want-this-fishing-season
• New ways to stop spiny water flea spread – Mesabi Tribune
https://www.mesabitribune.com/opinion/columnists/new-ways-to-stop-spiny-water-flea-spread/article_daea21e8-bca9-11eb-ae17-0b26c8aa0317.html

Subproject 15 Completed: 12/31/2021
FINAL ABSTRACT
Manuscript
Map
Visual

Sub-Project 16.2: AIS Impacts on Walleye Populations and Mercury Concentrations - $199,862 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Invasive zebra mussels impact lakes supporting walleye in Minnesota. Our research demonstrates that zebra mussels are associated with lower recruitment (reproduction and survival) of walleye in their first year. Furthermore, walleye and yellow perch alter their feeding habits in lakes with zebra mussels, which is associated with increased mercury concentrations.

OVERALL PROJECT OUTCOME AND RESULTS

Invasive zebra mussels profoundly affect lake ecosystems, but their impacts on walleye are not well understood. We used a multi-pronged approach to understanding zebra mussel impacts on walleye in Minnesota lakes. First, we evaluated how walleye recruitment (reproduction and survival) to their first fall was affected. We used statistical models applied to data collected by the Minnesota Department of Natural Resources to quantify changes in walleye recruitment. Walleye recruitment declined by ~41% following zebra mussel invasion. Additionally, lakes with zebra mussels supported the highest walleye recruitment prior to invasion, suggesting that zebra mussels invade high quality walleye lakes. Next, we evaluated how zebra mussels influence food webs supporting walleye and yellow perch, and how food web changes influence mercury concentrations in fish tissue. Using stable isotope analysis, we found that walleye and yellow perch in zebra mussel invaded lakes use 36-50% more nearshore food resources compared to those in uninvaded lakes. Mercury concentrations in fish were also influenced by zebra mussels; mercury in fish tissue was 66% higher for adult walleye and 91% higher for adult yellow perch in lakes containing zebra mussels compared to those in uninvaded lakes. On average, mercury concentrations in 16-inch walleye from lakes containing zebra mussels were 0.28 ppm, above the 0.2 ppm threshold triggering human consumption advisories by the Minnesota Department of Health. Zebra mussel-induced changes have important implications for walleye in Minnesota lakes. Lower walleye recruitment in invaded lakes may influence abundance at later life stages, which could influence harvest and stocking plans. Walleye were able to persist on nearshore food resources following zebra mussel invasions, but mercury concentrations were higher in these fish with important implications for human consumption. Given the significance of the impacts of zebra mussels documented in our study, preventing zebra mussel invasions into additional walleye lakes is critical.

PROJECT RESULTS USE AND DISSEMINATION

We have provided regular updates of our progress to scientists, managers, and the public via oral presentations and posters. PI Hansen and graduate student Kundel are members of the MN DNR Walleye-Zebra Mussel task force, and our research on the effects of zebra mussels on walleye recruitment has been critical for informing their approach to monitoring and managing for zebra mussel invasions. We have presented our results directly to MN DNR fisheries staff, at the MAISRC showcase, and at a national conference, as well as through several public virtual sessions. Progress on each objective was delayed due to the Covid-19 pandemic, and we are in the process of preparing

manuscripts describing our results for peer-reviewed publications.

Presentation Recordings
• 2020 MAISRC Research & Management Showcase Presentation
https://z.umn.edu/2020ShowcaseZMWalleye

Factsheets/Informational Documents
• Zebra mussel impacts on walleye populations and mercury concentrations: A collaborative project investigating the connections between zebra mussels, changes to lake food webs, and walleye success
https://z.umn.edu/HansenWalleyeFactsheet

Subproject 16.2 Completed: 12/31/2021
FINAL ABSTRACT
Factsheet
Map
Visual

Sub-Project 18.2: Genetics to Improve Hybrid and Eurasian Watermilfoil Management - $236,423 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Invasive Eurasian and native northern watermilfoil can hybridize and we identified hybrid watermilfoil in 39 lakes across the state. Hybrid watermilfoil is genetically more diverse than Eurasian watermilfoil and has potential to be more invasive and resistant to herbicides; several potentially problematic genotypes have been identified for further study.

OVERALL PROJECT OUTCOME AND RESULTS
Invasive Eurasian and native northern watermilfoil can hybridize and some genotypes of hybrid watermilfoil have been shown to be more invasive or resistant to herbicidal control. Our aim was to determine the occurrence and distribution of hybrid watermilfoil in Minnesota, assess the response of different genotypes to herbicidal management, identify potentially problematic genotypes and assess the response of some of these genotypes to herbicide in controlled laboratory conditions. We assessed watermilfoil genetic composition in 81 waterbodies in Minnesota; 55 lakes had pure Eurasian, mostly one widespread genotype that was found in 52 lakes. Eight other Eurasian genotypes were found. We identified hybrid watermilfoil in 39 lakes across the state, mostly, but not entirely, in the Twin Cities

Metro. Hybrid watermilfoil is genetically more diverse than Eurasian watermilfoil and 82 genotypes were found. Most lakes have one unique genotype of hybrid but multiple genotypes were found in several lakes and 26 have been identified in Lake Minnetonka. One hybrid genotype has been found in 10 lakes. No clearly problematic genotypes have been identified in Minnesota but we did find changes in genotype frequency with management in an assessment of 5 managed waterbodies and 3 reference waterbodies over 3 years. Several hybrid genotypes have expanded while Eurasian decreased and two hybrids from Lake Minnetonka have persistently rebounded after control. We also identified one genotype of northern watermilfoil that may be less affected by herbicide treatment. We conducted laboratory performance and herbicide challenge tests with the widespread Eurasian genotype and 4 hybrid genotypes. Additional experiments are needed but preliminary results suggest that two hybrid genotypes may be more tolerant of 2,4-D than the widespread Eurasian and two other hybrid genotypes. Continued identification of hybrid genotypes and response to management will improve milfoil management by allowing manager to appropriate controls for their particular populations.

PROJECT RESULTS USE AND DISSEMINATION

We presented our insights and results and interacted with stakeholders at the MAISRC Showcase in 2019 and 2020 and held two in person and two virtual meetings with stakeholders to discuss observations and interest in genetic testing. We provided information to update the MAISRC website and hybrid watermilfoil fact sheet and developed a genotyping fact sheet for distribution by MAISRC and the DNR. We gave 8 presentations at regional and national scientific meetings and published three papers: Eltawely et al. 2020, Pashnick and Thum 2020, and Thum et al. 2020. In addition, two Masters projects, Eltawely 2019 and Gannon 2021 were completed.

We are in regular contact with the DNR, consultants and applicators about our results, which have been used to inform management actions.

Peer-reviewed publications:

Eltawely, J. A., R. M. Newman, and R. A. Thum. 2020. Factors Influencing the Distribution of Invasive Hybrid (Myriophyllum Spicatum x M. Sibiricum) Watermilfoil and Parental Taxa in Minnesota. Diversity 12(3):120. https://doi.org/10.3390/d12030120

Pashnick, J., and R. A. Thum. 2020. Comparison of molecular markers to distinguish genotypes of Eurasian watermilfoil, northern watermilfoil, and their hybrids. Journal of Aquatic Plant Management 58(1):61-71. http://www.apms.org/wp/wp-content/uploads/japm-58-01-61-full.pdf

Thum, R.A., Chorak, G.M., Newman, R.M., Eltawely, J.A., Latimore, J., Elgin, E., and Parks, S. 2020. Genetic diversity and differentiation in populations of invasive Eurasian (Myriophyllum spicatum) and hybrid (Myriophyllum spicatum × Myriophyllum sibiricum) watermilfoil. Invasive Plant Science and Management 13(2): 59-67. https://doi.org/10.1017/inp.2020.12

Masters' theses:

Eltawely, J. A. 2019. Distribution of Eurasian and hybrid watermilfoil in Minnesota. Water Resources Science Masters Plan B Paper, University of Minnesota, St. Paul, MN. https://hdl.handle.net/11299/211341

Gannon, K. A. 2021. Integrating DNA fingerprinting of invasive watermilfoil strains into aquatic

vegetation monitoring and assessment. Plant Sciences Masters of Science Thesis, Montana State University, Bozeman, MT.

Subproject 18.2 Completed: 06/30/2021
FINAL ABSTRACT
Graphic

Sub-Project 20: A Novel Technology for eDNA Collection and Concentration - ML2013 $94,599 / ML2017 $96,264 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The development of a novel filter capable of efficiently extracting Environmental DNA (eDNA) from water, and enabling rapid filtration of large volumes of samples at a reasonable cost, is expected to help convert the eDNA technology from a research curiosity into a routine tool for ecosystem protection and monitoring, and evidence-based management of invasive species.

OVERALL PROJECT OUTCOME AND RESULTS
Background/Context: Environmental DNA (eDNA) is the genetic material (genomic DNA) obtained directly from environmental samples such water. Collection and analysis of eDNA has the potential to provide actionable information on the presence and distribution of aquatic invasive species.

Challenge: The major challenge is that the results obtained from eDNA techniques currently do not always correlate with traditional netting data due to the size and quality of sampling. Unlocking the potential of eDNA requires disruption in sampling methods and tools.

Objectives: This project aimed to develop a novel aquatic eDNA collection and concentration technology for more efficient, reliable and cost-effective screening for not only invasive aquatic organisms and pathogens but also native and endangered species. The technology would significantly enable and empower aquatic ecosystem survey and management programs in Minnesota. Specifically, we aimed to 1) develop an eDNA nanofilter that specifically and rapidly captures nucleic acids (DNA, RNA) from water and enable the processing of large volumes of samples within a short period of time, 2) Verify increased eDNA sampling efficiency of the new nanofilter in field settings (proof-of-concept)

Results and Accomplishments: We have successfully developed a new eDNA filter that captures 50-100% of eDNA within 10 seconds. Commercial kits are incapable of capturing free eDNA. The loading capacity of the new filter is up to 5 mg/g, meaning that 1 g of filter can capture up to 5 mg of DNA. This is a

record-breaking capacity that enables the filtration of large volumes of water with one filter, knowing that surface water contains usually 10 ng/L of eDNA.

Following the COVID-19 pandemic, we have adapted the nonfilter to develop an RNA extraction kit for SARS-CoV-2. The new kit was evaluated by the University of Minnesota COVID-19 Diagnostic Laboratory on 80 patient samples, and it showed that our kit has a 100% specificity and 94% sensitivity, which is respectively 12.8% and 5.4% higher than the widely used Qiagen kits

Significance and Impact to Minnesota: Ecosystem conservation managers have been relatively reluctant to use eDNA as a routine tool for ecosystems monitoring. The results obtained here can have a significant impact on the widespread adoption of eDNA technology, which will help the State enhance the accuracy and quality of the data and improve decision making for the management of invasive species. This work has also led to starting a new company, which is expected to accelerate the transfer of the technology to the market, and enhance the industry capacity to respond to the State's need for AIS management.

PROJECT RESULTS USE AND DISSEMINATION

The results obtained in this project have been presented at three conferences and meetings and will be published through four scientific publications that are currently in process. The work has also been highlighted by the University of Minnesota news service and more media coverage is expected after manuscript publication. The work conducted in this project has also led to the foundation of a new technology company that is expected to take the eDNA filter technology to the market during 2021.

Presentations:

• Zarouri, A., A. Abbas. September 2019. Enhancing fish surveys: A novel technology for environmental DNA capture. MAISRC Research and Management Showcase. Saint Paul, MN.

• Quichen, D., A. Zarouri, A. Abbas. September 2019. A Novel Technology for Environmental DNA Collection and Concentration. American Fisheries Society and The Wildlife Society Conference. Reno, NV.

• Zarouri, A., Q. Dong, A. Abbas. October 2019. A Novel Technology for Environmental DNA Collection and Concentration. 2019 Department of Bioproducts and Biosystems Engineering Research Poster Session. Saint Paul, MN.

Media:

• Detection connections. CFANS News. 9 July 2020. https://cfans.umn.edu/news/abbas-lab-covid-19-update

Attachments:

• Photo of the eDNA nanofilter that was developed as a part of this project.

Subproject 20 Completed: 06/30/2020

FINAL ABSTRACT

Photo

Sub-Project 21.2: Field validation of mulitbeam sonar zebra mussel detection (Year 1)** - $14,247 TF

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Subproject 21.2 Completed: 06/30/2020

Sub-Project 22: Copper-Based Control – Zebra Mussel Settlement and Non-Target Impacts - UMN ML2013 $54,438 / ML2017 $30,300 and USGS ML2013 $12,428 / ML2017 $121,790 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS

A 10-day low-dose copper treatment of an enclosed bay in Lake Minnetonka (Minnesota) was highly effective at reducing the abundance of zebra mussel veligers and preventing zebra mussel settlement success. The treatment did cause some nontarget effects including, but not limited to, reductions in native zooplankton and benthic invertebrate abundance.

OVERALL PROJECT OUTCOME AND RESULTS

This study evaluated a low-dose copper treatment for zebra mussel (Dreissena polymorpha Pallas 1771) suppression by maintaining a mean copper concentration of 60 µg/L in waters above the thermocline for 10 consecutive days in St. Albans Bay (66.3-ha) of Lake Minnetonka, Minnesota. Robinson Bay (37.2-ha, Lake Minnetonka) was a control site. The volume of EarthTec QZ applied during five every-other-day applications was determined using copper concentrations measured in the field.

Treatment effects on zebra mussels lifestages were evaluated by analyzing changes in veliger abundance, juvenile settlement, benthic abundance, and adult survival. Treatment effects on nontargets were evaluated by analyzing changes in water chemistry properties, chlorophyll a, native fish (4 species) survival, native mussel (1 species) survival, native zooplankton abundance and richness, and native benthic invertebrate abundance and richness.

The copper concentration was maintained above 60 µg/L during the treatment period and returned to background levels between 60 and 90 days after treatment. The treatment adversely affected all life stages of zebra mussels throughout the study period. In the treated bay, veliger density was near zero

14 days after treatment, a strong reduction in juvenile settlement was observed, zebra mussel benthic density was sparse after treatment, and the odds of adult survival was substantially reduced. Detectable nontarget treatment-related effects included reductions in zooplankton abundance, chlorophyll a, and fathead minnow survival. Elevated copper residues in fish and mussel tissues were also observed. Decreases in benthic invertebrate abundance, secchi disk readings, and dissolved oxygen concentration were also observed after the treatment.

The data from this study can be used to assist in assessing if low-dose copper treatments are an appropriate zebra mussel management strategy for a waterbody. Any use of trade, firm, or product names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Government.

PROJECT RESULTS USE AND DISSEMINATION

Publications:

• Luoma J.A., Barbour M.T., and Severson T.J. (2020). Data Release: Copper-based control: zebra mussel settlement and non-target impacts. U.S. Geological Survey. Data Release. https://doi.org/10.5066/P9B9NUQM.

Presentations:

• Barbour M.T., Luoma J.A., Severson T.J., Wise J.K., and Dahlberg A. (2019). Low-dose copper-based control: zebra mussel settlement and non-target impacts. MAISRC Research and Management Showcase, University of Minnesota Continuing Education and Conference Center, Saint Paul, Minnesota.

• Dahlberg A., Phelps N., Waller D., Luoma J., and Barbour M. (2020). Low-dose copper-based control: zebra mussel settlement and non-target impacts (webinar). AIS Detectors Program, August 26, 2020, https://www.maisrc.umn.edu/ais-detectors/webinars.

• Dahlberg A., Phelps N., Waller D., Luoma J., and Barbour M. (2020). Low-dose copper-based control: zebra mussel settlement and non-target impacts (webinar). Invasive Mussel Collaborative, August 27, 2020.

Media:

• UMN Driven to Discover video: Guardians of the Lake (2019). https://twin-cities.umn.edu/discover/guardians-lake

• Zebra mussels research project planned for Lake Minnetonka this summer. Melissa Turtinen, Southwest News Media. 23 April 2019. https://www.swnewsmedia.com/lakeshore_weekly/news/local/zebra-mussels-research-project-planned-forlake- minnetonka-this-summer/article_750497a4-a492-5020-868b-6d752887fa0b.html

• St. Alban's, Robinson's bays will be site of zebra mussel research project. Sabina Badola, Sun Sailor. 16 April 1029. https://www.hometownsource.com/sun_sailor/free/st-alban-s-robinson-s-bays-will-be-site-of-zebra-musselresearch-project/article_fe8a1ea4-607c-11e9-aafc-63c0878d1728.html

Attachments:

• Zebra Mussel Control with Low-Dose Copper (handout)
• Photos from field work
• Effects Map

Subproject 22 Completed: 06/30/2020

FINAL ABSTRACT

Graphic

Sub-Project 23: Public Values of Aquatic Invasive Species Management - ML2013 $131,845 / ML2017 $110,245 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Minnesotans hold great value for Aquatic Invasive Species Management, both to lakes they visit and to waterbodies in the state as a whole and are willing to pay significantly for it. Minnesotans are concerned about AIS and are generally supportive of AIS management actions and policies.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesota hosts a number of aquatic invasive species (AIS), which have far-reaching impacts on Minnesota's waterbodies, and subsequently its population. However, little was known about how Minnesotans value AIS, as well as costs associated with AIS management. To address this, we collected data on aquatic invasive species management and costs, public perceptions, values, knowledge, and willingness to pay for aquatic invasive species management via several surveys of different types spanning 2019 to 2021. Surveys of watershed districts and soil and water conservation districts provided data from 92 lakes across 12 counties, showing that carp management is a priority in Minnesota. We also were able to collect data on costs and types of management employed. On the individual side, an onsite survey of approximately 1000 people visiting lakes in the summer showed us visitors are willing to pay for AIS management at the lakes they are visiting and hold significant value for Minnesota's water resources, though individual AIS species present are not impactful for these social values. We also collected data through a mail survey of about 300 people, which confirmed Minnesotans' intrinsic value for water resources. Many residents are willing to pay for AIS management statewide, meaning they do not have to directly visit or use a lake to find value in it. This project is important as it provides data to support the viewpoint that Minnesotans do in fact have great value for AIS management and are willing to pay to expand management across the state.

PROJECT RESULTS USE AND DISSEMINATION
This project's findings have been disseminated through nine oral and poster presentations to researchers, resource professionals (e.g., Minnesota Department of Natural Resources), lake associations, policy makers, and the general public (e.g., lakeshore residents) at professional conferences (e.g., Minnesota Water Resources Conference), Minnesota Aquatic Invasive Species Research Center (MAISRC) Research & Management Showcase, and invited seminars (e.g., Minnesota DNR, AIS Detectors' Aquatic Invasive Species Webinar Series). We have published one open access article in a peer-reviewed journal (PLOS ONE). We have developed a fact sheet highlighting findings from the statewide survey conducted with Minnesota residents. In coordination with MAISRC, we developed a handout of findings from the survey conducted with recreationists at four Minnesota lakes. We plan to

continue to disseminate study findings through presentations and peer-reviewed journal articles. We have submitted two abstracts to the International Association for Society and Natural Resources Conference and Universities Council on Water Resources Annual Conference to be held in June, 2022 and are currently preparing three additional manuscripts for submission to peer-reviewed journals.

Peer-Reviewed Publications
• Levers, L., & Pradhananga, A. (2021). Recreationist Willingness to Pay for Aquatic Invasive Species Management. PLOS ONE. https://doi.org/10.1371/journal.pone.0246860

Presentation Recordings/Videos
• 2021 MAISRC Research & Management Showcase Common Carp Panel
https://z.umn.edu/2021ShowcaseCommonCarpPanel
• AIS Detectors Webinar: Recreationists' Willingness to Pay for Aquatic Invasive Species Management
https://z.umn.edu/DetectorsWebinarWillingnessToPay
• MAISRC Video: Valuing Aquatic Invasive Species Management
https://z.umn.edu/MAISRCValuingAISManagement

Subproject 23 Completed: 12/31/2021
FINAL ABSTRACT
Factsheet
PLOS ONE Manuscript
Statewide Resident Survey Factsheet

Sub-Project 24: Genetic Method for Control of Invasive Fish Species - ML2013 $110,112 / ML2017 $140,004 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
MAISRC has laid the groundwork to develop innovative genetic biocontrol approaches to be used in the fight against invasive carp.

OVERALL PROJECT OUTCOME AND RESULTS
Invasive fish species present an estimated $5.4 billion burden on our domestic economy, and much of that extends to the lakes and rivers of Minnesota. For example, the foraging habits of the invasive common carp, Cyprinus carpio, diminishes water quality, reduces vegetative cover and waterfowl numbers, and reduce the ability of lakes to absorb nutrients that enter water systems through agricultural runoff. Current control methods have not been able to stem the tide of invasive carp and other fish species, so improved strategies are needed. The overall goal of this project is to demonstrate

a novel approach for controlling aquatic invasive species using invasive carp species as proof-of-concept. Success of this project would lead to its implementation in other aquatic invasive species (AIS), including Asian carp and zebra mussels.

Several major obstacles had to be overcome on this project to lay the foundation for genetic biocontrol of invasive carp. These included (i) Developing husbandry for year-round carp spawning in the MAISRC Containment Lab, (ii) Demonstrating transgenesis of C. carpio, (iii) Testing genetic reagents in a model laboratory fish that will be needed to engineer carp, and (iv) Performing a survey to gauge public perceptions of carp genetic biocontrol. We accomplished these project goals within a one-year no-cost extension to the project funding.

The impact of our results is that we are now primed to engineer carp genetic biocontrol agents in the lab during the next phase of this award, which will begin January 2022. There is still substantial work to be done before this will directly benefit Minnesotans. Specifically, we need to demonstrate a proof-of-concept carp biocontrol system in the laboratory; perform safety/efficacy testing; obtain permits for field trials; and eventually work with key stakeholders to use this new tool in the fight against invasive carp. The overall process is expected to take 10-15 years.

PROJECT RESULTS USE AND DISSEMINATION
Data generated from this subproject is expected to be included in three peer reviewed publications. These include results from the public survey (expected submission Summer 2021), results from the carp husbandry/transgenesis procedure (expected submission Winter 2021), and agent-based modeling results (waiting for accompanying wet-lab experimental confirmation).

In addition to these primary research reports, one book chapter that describes the techniques developed under this subproject has already been published:

Bajer P, Ghosal R, Maselko M, Smanski MJ, Lechelt JD, Hansen G, Kornis M (2019) Biological control of invasive fish and aquatic invertebrates: a brief review with case studies. Management of Biological Invasions. 10: 200-226.

Subproject 24 Completed: 06/30/2021
FINAL ABSTRACT
Graphic

Sub-Project 25: What's in Your Bucket? Quantifying AIS Introduction Risk - ML2013 $111,642 / ML2017 $84,094 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Live baitfish are popular among Minnesota anglers, but their illegal release is a known risk factor for spreading harmful diseases to wild fish populations. Our research identified high-risk pathogens in Minnesota, estimated the number of times anglers release an infected baitfish each year, and identified opportunities for strategic management intervention.

OVERALL PROJECT OUTCOME AND RESULTS

In Minnesota, the illegal release of live baitfish by anglers has been identified as a weak point in our efforts to prevent the spread of aquatic invasive species and pathogenic microbes, however the magnitude of the risk and evidence-based opportunities for intervention had not been well studied. The purpose of this project was to assess the risk of fish pathogen introduction via illegal release of live baitfish by Minnesota anglers to inform strategic management strategies to reduce that risk. First, we created a semi-quantitative framework to evaluate the threat of baitfish pathogens in Minnesota and used it to rank pathogens so managers can prioritize resources. We then conducted a statewide survey of anglers to quantify risky behaviors and used those data to parameterize a risk assessment model for high-risk pathogens to estimate the number of risky trips that occur in a given year under a variety of scenarios. Our results were variable, indicating a wide range of outcomes depending on current management strategies and pathogen prevalence. For example, with strong surveillance and controls in place for the viral hemorrhagic septicemia virus, the number of risky trips is limited in most scenarios. However, for high-risk pathogens (Ovipleistophora ovariae, Asian fish tapeworm) for which no controls are in place, the large number of anglers, frequency of illegal release, and the popularity of susceptible baitfish species, can result in hundreds of thousands of risky trips each year, even in low-prevalence scenarios. Ensuring a safe, pathogen-free bait supply and decreasing the percentage of anglers who release their baitfish can reduce pathogen introduction risk while preserving the important cultural and economic benefits of recreational angling. Our project provides evidence-based tools for prioritizing scarce resources and identifying weak points in our management strategies so we can improve them to protect our valuable fish and fishing resources.

PROJECT RESULTS USE AND DISSEMINATION

Throughout this process we have communicated and collaborated with technical experts, managers, and members of the public alike. In addition to the three manuscripts either published or in prep for this project, we have presented this material in a variety of settings. Results from this project have been shared via presentations to local (UMN Ecosystem Health Group, MAISRC Research Showcase, MNDNR AIS Working Group meetings, Minnesota Lakes and Rivers Advocates), statewide (MN Chapter of the American Fisheries Society, UMN Extension Webinars), regional (Upper Midwest Invasive Species Conference), and national (North American Invasive Species Management Association, American Fisheries Society Fish Health Seminar) audiences and hundreds of individual participants. We have also maintained close contact with DNR Fisheries and AIS staff who have periodically served as unfunded collaborators and advisers on the project, and we worked with a number of AIS Detector volunteers in implementing the survey portion of the project.

Subproject 25 Completed: 12/30/2020

FINAL ABSTRACT

Graphic

Sub-Project 28: Evaluating Innovative Coatings to Suppress Priority AIS - $51,234 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Biofouling is a natural phenomenon that includes the adhesion of Zebra mussels to structures or boats and contribute to their spread in Minnesota waters. Current antifouling coatings are environmentally toxic. We demonstrate the efficacy of an eco-friendly coating technology that could help mitigate the spread of sessile invasive species, while minimizing non-target impacts.

OVERALL PROJECT OUTCOME AND RESULTS
Biofouling is a natural phenomenon that sticks on structures or boats. It is a vector for the spread of numerous invasive species in Minnesota waters. A current way of fighting biofouling involves using metals that are harmful to the environment. We successfully evaluated a new generation of coatings containing a non-toxic, antifouling, biological molecule, and demonstrate that it reduces the adhesion of invasive species. These coatings could help mitigate the spread of sessile invasive species not only in coastal and inland waterways but also on recreational and industrial equipment surfaces, while minimizing non-target impacts.

Problem: Replace current toxic antifouling coatings with coatings containing a non-toxic, antifouling, biological molecule to mitigate the spread of sessile invasive species while minimizing non-target impacts.

Methodology: We took advantage of our unique technical and scientific edges to evaluate the potential of this technology to replace toxic biocides currently used to limit biofouling. Coated samples were submerged in the field in three different sites in Minnesota, including infested sites, and samples were analyzed using microscopies, organisms were quantified and measured, and surface microbial communities determined.

Results and Significance: Biofouling is a main vector for the spread of aquatic invasive species. Current antifouling solutions are both partly effective and highly toxic to the environment. In this proof-of-concept project, we demonstrate that our non-toxic enzyme technology can prevent the adhesion of AIS on submerged surfaces. We show that in three different Minnesotan field sites that enzymatic coatings can outperform coatings containing biocides, and prevent Zebra mussels adhesion to polycarbonate surface over the course of two summer months. This enzyme-based coatings could help mitigate the spread of sessile invasive species in Minnesota and beyond. These results evidence that this novel technology has the potential to replace toxic antifouling coatings and help mitigate the spread of AIS in Minnesota and beyond.

PROJECT RESULTS USE AND DISSEMINATION
We have disseminated our findings to stakeholders to increase awareness of our technology and allow us to learn about market landscape and end-users needs. In particular, we discussed with lake owner associations leaders at and representative of the Legislature at the AIS Research and Management Showcase. We also have communicated via seminars and presentation with other stakeholders, including Dupont, the MN DNR, the Bureau of Reclamation, and presented our results at the iPrime meeting, an academic-industrial meeting where key stakeholders were present, including 3M, BASF, Evonik and Ecolab. We also used communication services at the Biotechnology Institute to disseminate our results to the public in the form of a blog article and we are preparing two research articles to communicate to the scientific community.

Presentations:
• Huang, Hicks, Elias. Suppressing Microbial Communication to Mitigate the Spread of AIS. 9/18/2019. MAISRC Research and Management Showcase.
• Elias. Interference in Microbial Signaling: a powerful way to control microbes and study their languages. 12/3/2019. Presentation to the bureau of Reclamation.
• Elias. Interference in Microbial Signaling: a powerful way to control microbes and study their languages. 11/18/2019. Presentation to Dupont.
• Elias. New Advances in Controlling Microbial Behaviors by Interfering in Microbial Speech. 8/6/2020. iPrime national meeting.

Media:
• Enzyme-based coatings developed at the University of Minnesota help protect port infrastructure by disrupting the signals underwater bacteria use to communicate. Nick Minor and Kristal Leebrick, Gateway: Signal and Noise. 18 May 2020. https://gateway.bti.umn.edu/2020/05/18/signal-and-noise/

Attachments:
• Figure of results of coupons coated with paint containing control protein.

Subproject 28 Completed: 06/30/2021
FINAL ABSTRACT
Graphic

Sub-Project 30: Managing Midwestern Aquatic Invasions in a Changing Climate - UMN $16,238 / IU $22,762 TF

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SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Managing AIS in Minnesota's water requires integrating ecological science to understand invaders' impacts and how they respond to different management strategies, climate science to understand changes under changing conditions, and social science to understand the preferences of communities and how they make decisions. This project helps us understand all three.

OVERALL PROJECT OUTCOME AND RESULTS
Nitellopsis obtusa (starry stonewort) is a freshwater alga that is a key emerging invader in Minnesota and the upper Midwest that displaces native aquatic plant communities and restructures lake ecosystems. We conducted an interdisciplinary project to evaluate how starry stonewort will respond to climate change and to understand community decision-making about management options incorporating both ecological and social factors. We did this by utilizing a latitudinal gradient in the range of starry stonewort, from Indiana to Minnesota, as well as inter-annual variability as proxies for potential climate change. Across the region we monitored invasions to evaluate community effects of starry stonewort and conducted interviews with stakeholders to evaluate perceptions of starry stonewort impacts and management preferences. We found that starry stonewort can expand rapidly, but invasion dynamics were highly variable and influenced by climatological conditions. In some particular circumstances expansion was very limited and, in some years, native species were able to recover in areas where starry stonewort abundances decreased. From stakeholder interviews we learned that current management strategies, perceptions about the importance of addressing invasive species, and stakeholders' goals differed between states and stakeholder types. We also found that there were two distinct sets of values that motivated stakeholders, where individuals either viewed lakes as a public good or an exclusive resource.

This information can help predictions of further spread of starry stonewort and of the potential impacts of starry stonewort invasions once established. Additionally, our results can help local stakeholders understand invasion dynamics and impacts to inform their decisions about management options. At the same time our social science efforts can help inform state and regional resource managers about how they can best assist stakeholders in their decisions and our ecological efforts can help develop standards (such as monitoring protocols) that should be included in permitting for treatments.

PROJECT RESULTS USE AND DISSEMINATION
We have presented results from this project in a number of academic, governmental, and public presentations including at the MAISRC Showcase, a MAISRC detectors webinar, the Indiana Invasive Species Council, the Indiana University Environmental Resilience Institute Symposium, Hoosier Flyfishers, Boston University, and the University of Buffalo. We are also currently drafting a policy brief based on our social science efforts (in coordination with a manuscript about to be submitted) that will be shared with MAISRC.

Presentation Recordings/Videos

- 2021 MAISRC Research & Management Showcase Presentation https://z.umn.edu/2020ShowcaseStarryClimate
- AIS Detectors Webinar: Understanding Starry Stonewort Invasions in a Changing Climate https://z.umn.edu/DetectorsWebinarStarryClimate

Subproject 30 Completed: 06/30/2022
FINAL ABSTRACT

Subd. 06b Emerald Ash Borer Biocontrol - Phase III - $729,000 TF (FY2018)

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Appropriation Language
$729,000 the first year is from the trust fund to the commissioner of agriculture in cooperation with the Board of Regents of the University of Minnesota to implement biocontrol of emerald ash borer using a newly approved parasitic wasp, assess the impact of the statewide program, and engage citizen volunteers. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Biological control has been effectively implemented, which has led to increasing recoveries of parasitoids over time. Cold tolerance testing of Spathius galinae resulted in a forecasting model of survival in North America. The Buprestidae of Minnesota guide was created and provides baseline data on jewel beetles present in Minnesota.

OVERALL PROJECT OUTCOME AND RESULTS
We have successfully completed all activities. We are pleased to report that the effective implementation of EAB biocontrol has led to increasing recoveries of the larval parasitoid Tetrastichus planipennisi and the egg parasitoid Oobius agrili through time based on data analysis in Activity 2. We produced several peer-reviewed scientific publications (with full credit to LCCMR) on Activities 3 and 4. For Activity 3, we evaluated the cold hardiness of the larval parasitoid Spathius galinae and published a study forecasting its survival in North America (Wittman, Aukema, Duan, and Venette (2021) Forecasting overwintering mortality of Spathius galinae in North America. Biological Control. 160: 104694). The insect will survive best in areas where winter temperatures remain above -20 Fahrenheit. For Activity 4, we published two journal articles detailing a checklist of buprestids found in Minnesota (Hallinen, Steffens, Schultz, Aukema (2021) The Buprestidae (Coleoptera) of Minnesota, with a discussion of the emerald ash borer, Agrilus planipennis Fairmaire. The Coleopterists Bulletin 75: 173-190) as well as a study on their habitat features (Hallinen, Wittman, Aukema (2020) Factors associated with diversity and

distribution of buprestid prey captured by foraging Cerceris fumipennis (Hymenoptera: Crabronidae) (Environmental Entomology 49: 1363-13763). These works provide critical information on what is here, now, so we have a basis of comparison for when a new invasive wood-boring beetle in the same family as emerald ash borer arrives in the future. We then published, from the scientific checklist, a free and accessible guide (The Buprestidae of Minnesota) that can be downloaded from permalink. This latter guide contains not only specimen photos but also maps of the distribution record and dates of last collection by decade. All four publications are submitted with this final report.

PROJECT RESULTS USE AND DISSEMINATION

Throughout the duration of the project, results were disseminated through a variety of venues. A wide and diverse audience was reached through interviews with local press, informational webinars, outdoor training sessions held throughout the state, and at academic and natural resource professional conferences and meetings. Parasitoid release and recovery results from activity 1 and 2 can be viewed through an interactive online map. Through the work on activity 3 of this project, models have been created and published forecasting the expected overwintering mortality of the introduced larval parasitoid Spathius galinae. This information is of vital importance to the successful implementation of EAB biological control throughout North America (Wittman, Aukema, Duan, and Venette (2021) Forecasting overwintering mortality of Spathius galinae in North America. Biological Control. 160: 104694). Activity 4 of this project produced tremendously valuable baseline data on the buprestids found in Minnesota. Two journal articles were published detailing a checklist of buprestids found in Minnesota (Hallinen, Steffens, Schultz, Aukema (2021) The Buprestidae (Coleoptera) of Minnesota, with a discussion of the emerald ash borer, Agrilus planipennis Fairmaire. The Coleopterists Bulletin 75: 173-190) as well as a study on their habitat features (Hallinen, Wittman, Aukema (2020) Factors associated with diversity and distribution of buprestid prey captured by foraging Cerceris fumipennis (Hymenoptera: Crabronidae) (Environmental Entomology 49: 1363-13763). A free and accessible guide was created from these publications called The Buprestidae of Minnesota and can be downloaded from the permalink.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 06c Invasive Bighead Carp and Silver Carp and Native Fish Evaluation - Phase II - $500,000 TF (FY2018)

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Appropriation Language
$500,000 the first year is from the trust fund to the commissioner of natural resources to continue invasive bighead and silver carp monitoring in the Mississippi River and tributaries through advanced acoustic telemetry and assess food chains to determine how native species might prevent invasive bighead and silver carp establishment. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Over the past four years, this project tested new capture methods, learned locations where invasive carp are vulnerable to capture, and removed over 150 fish. Our goal in learning how best to remove invasive carp is to disrupt the potential for spawning that could lead to their establishment in Minnesota waters.

OVERALL PROJECT OUTCOME AND RESULTS
Invasive carp have caused severe ecological damage to the Illinois, Missouri, and lower Mississippi River ecosystems, and threaten to do the same if they become established in Minnesota. Increased monitoring by the Minnesota Department of Natural Resource (DNR), funded in part by ENRTF, has found invasive carp becoming more numerous and widespread in Minnesota in recent years. However, our mulit-year monitoring of larval fish has not documented any reproduction in Minnesota waters to date, indicating they are not yet established. ENRT funding has led to significant gains in our understanding of where, when and how to capture and remove these fish and disrupt their establishment.

An array of receivers used in tracking tagged fish has been instrumental in identifying movement patterns and season habitat preferences of invasive carp and native species. We are learning the seasonal use of invasive carp habitats, which has proven useful in removal and management efforts. Tracking of a radio-tagged invasive carp allowed us to know when and where to target removal efforts, and has directly led to the capture of six invasive carp. Applying what we have learned to places where we don't have tagged fish, ENTRF funded staff conducted 364 days of field sampling, including over 139,000 feet of gill net deployed, over 7,300 minutes of electrofishing and over 134 days of monitored/contracted commercial fishing. This resulted in the removal of over 150 invasive carp during the grant period.

Our tracking tagged native fish assessing their habitat use through stable isotope analysis will be useful in the future to learn what effect invasive carp have on the native species.

PROJECT RESULTS USE AND DISSEMINATION
MN DNR invasive carp staff have provided a yearly Invasive Carp Sampling Report in which all sampling data is shared for anyone to view. MN DNR invasive carp staff also shares data with other state and federal agencies as well as Universities. In addition, numerous news outlets have covered the work done by the invasive carp crew over the last four years. Those articles and news stories can be located by doing a quick google search of Invasive carp in Minnesota.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 07 Air Quality, Climate Change, and Renewable Energy

Subd. 07b Assessment of Urban Air Pollution - $700,000 TF (FY2018)

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Appropriation Language
$700,000 the first year is from the trust fund to the commissioner of the Pollution Control Agency to set up and operate a network of 250 air pollution sensors at 50 sites to monitor fine particles, ozone, nitrogen oxides, sulfur dioxide, and carbon monoxide in each zip code for the cities of Minneapolis and St. Paul to assess variability of urban air pollution. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Air pollutant concentrations cannot be assumed to be the same across all zip codes in the cities of Minneapolis and St. Paul. There are local differences observed and these can influence quality of life where one lives. Monitor placement is very important in being able to detect these differences in neighborhoods.

OVERALL PROJECT OUTCOME AND RESULTS
Understanding small-scale differences in air pollution in urban areas is important for minimizing exposure to harmful air pollutants, particularly for vulnerable communities. This project is using new air-monitoring sensor technology to broaden our knowledge about air quality in Minneapolis and St. Paul. A total of 47 AQMESH air monitors were installed in the study area. 10 of these were co-located with existing MPCA regulatory monitors in order to more closely evaluate the use of sensor technology for accuracy. 14 monitors were located on parking lot light poles, in St. Paul public schools. 23 monitors were placed on Xcel light poles in Minneapolis in residential areas. Pollutants monitored were CO, NO, NO2, SO2, O3, PM2.5 and PM10. Data was collected from June 2019 to June 2021. In addition to the overall goal of seeing small scale differences in urban neighborhoods, this project had 3 main goals:

- Are there significant differences in pollutant concentrations between ZIP codes in the urban core?
- Are there areas with unusually high pollutant concentrations?
- Is this technology suitable for measuring small differences in air quality?

To investigate the last question, data from collocated sensors was compared to the regulatory monitoring data and it was found that there is a reasonably moderate confidence in the sensor data as they compare to the regulatory grade monitors. A strong relationship was also found between the sensor pods themselves, indicating that these would be a good tool for highlighting the differences in pollutant concentrations across the study area.

To further investigate the first 2 questions, data collected from all the sensors for all zip codes was analyzed using R (v 1.4.1717). Data was divided by region into North Minneapolis, South Minneapolis and St. Paul, based on the sensor location. Basic data statistics were computed, pollutant level charts were plotted and a generalized additive model was applied to look for trends and differences across the entire study area.

The analysis showed that although minimal, there are indeed micro level differences that can be observed. A very clear seasonal pattern can be seen for CO and O3 concentrations across all regions. Local events like the wide spread fires in May/June 2020 and July 4th fireworks tend to slightly increase the particulate counts for a short period. Sensor placement is very important as it affects the measurements.

Residents can use this data to be more cognizant about activities that happen around them in their neighborhoods, especially on days with bad AQI, which adds more particulates into the air making it unhealthy, and make appropriate changes for a healthier lifestyle. In St. Paul, monitoring was done in school parking lots, making these results suitable for education purposes and to understand how idling cars and buses effects short term air quality. Results specific to outdoor activities coinciding with drop off and pick up times can be useful. Extensive monitoring along roadways was not part of this project but some monitors along busy roads did show higher NOx levels. Overall, the air quality in Minneapolis and St. Paul is good but depending on where you live and any preexisting health conditions, it may affect ones quality of life. This study can inform future monitoring projects, specific areas where traffic could be examined more closely and looking at other local neighborhood sources of pollution.

PROJECT RESULTS USE AND DISSEMINATION
Over the past two years, various efforts were made to communicate results as and when they were analyzed. A project website was developed which is available on the MPCA's website. A tableau workbook is available with all the monitoring sites and data for all the pollutants being monitored. These can be filtered by site, pollutant and dates if desired.

Six month quarterly updates were provided to the LCCMR. In fall of 2018, project presentations were made in Minneapolis and St. Paul to solicit feedback on monitor placement. In Fall/winter 2019-2020, one year study results were presented at several meetings in Minneapolis and St. Paul to give residents an overview of what the monitors were showing in their respective zip codes. These results were also presented to the Metropolitan Council and other stakeholders.

Presentations will be made to community groups, stakeholders and interested parties. Community concerns, comments and additional analysis done, will be incorporated in the final report and published on the MPCA project webpage.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 07c Generation, Storage, and Utilization of Solar Energy - $500,000 TF (FY2018)

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Appropriation Language
$500,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, West Central Research and Outreach Center, Morris, to develop and demonstrate an integrated facility to generate electricity, shade dairy cattle, and provide energy storage and utilization from solar technologies at the West Central Research and Outreach Center, Morris. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The project benefited lakes and streams through the development of novel methods to reduce energy usage on farm and integrate cattle grazing and solar systems. We evaluated technology that that will reduce the carbon footprint through energy reduction from dairy farms in Minnesota that will improve environmental impact.

OVERALL PROJECT OUTCOME AND RESULTS
The work conducted at the University of Minnesota West Central Research and Outreach Center in Morris was were to investigate electrical energy use on dairy farms located in west central Minnesota and to evaluate the effects of shade use by cattle from solar photovoltaic systems. Measurements of baseline fossil fuel consumption within dairy production systems are scarce. Therefore, there is a need to discern where and how fossil fuel-derived energy is being used within dairy production systems. Baseline energy use data collection is the first step in addressing the demand for a reduced carbon footprint within dairy production systems. Energy use on five Midwest dairy farms was evaluated from July 2018 to June 2021. Through in-depth monitoring of electricity-consuming processes, it was found that electricity use can differ quite drastically in different types of milking systems and farms. Electricity on an annual basis per cow ranged from 400 kWh/cow in a low-input and grazing farm to 1,145 kWh/cow in an automated milking farm. To reduce electrical energy consumption as well as reduce the effects of heat stress in pastured dairy cows, producers may investigate using an agrivoltaic system. Biological effects of internal body temperature, milk production, and respiration rates and behavioral effects of activity, rumination, fly avoidance behaviors, and standing and lying time of the solar shade were evaluated. Results of this agrivoltaic system suggested that grazing cattle that have access to shade had lower respiration rates and lower body temperatures compared to cattle that do not have access to shade. This project suggests that improvement in Minnesota waterways and environment may be achieved through reduced use of fossil energy through integrating livestock and solar energy production systems.

PROJECT RESULTS USE AND DISSEMINATION
We have provided tours of the agrivoltaic system at the WCROC to legislators, farmers, and industry representatives. We have also hosted dairy field days and the Midwest Farm Energy Conference at the WCROC that have shown the results and solar system to the public as well. Over 10,000 people have viewed the solar system and have responded with favorable interest in the system. A graduate student

on the project presented an abstract at the ADSA Meeting and Waste to Worth conference. So far, 3 peer reviewed papers have been published with more to follow. The WCROC website provides the results of the project and YouTube videos for promotion of the project. A presentation was made at the global Virtual AgriVoltaics conference in 2021. This applied dairy energy and agrivoltaics projects was the Master's thesis of Kirsten Sharpe in the Department of Animal Science at the University of Minnesota and she defended her thesis in 2020.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 07d District Heating with Renewable Biomass at Camp Ripley Training Center - $1,000,000 TF (FY2018)

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Appropriation Language
$1,000,000 the first year is from the trust fund to the commissioner of military affairs to install a 5,000,000-BTU centralized biomass boiler system utilizing the forestry management at Camp Ripley. This appropriation must be matched by at least $900,000 of nonstate money and must be committed by December 31, 2017. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The scope of this project was to install a biomass heating plant that would service 7 Buildings including mechanical and distribution systems. We received an architect estimate and the base cost for the project in total was $7,122,035.

OVERALL PROJECT OUTCOME AND RESULTS
Due to these headwinds, Current Project estimates (Steel prices, metal prices in particular; (Piping), and lumber prices, etc), we lowered the scale of the project to just the biomass heating plant and underground piping and connections to just 2 facilities, and that bid estimate came in at $4,407,008.

National Guard Bureau and DMA leadership requested that we reassess the Life Cycle Cost Analysis (LCCA's) numbers on this project. The Saving's to Investment Ratio (SIR) changed from 2.31 during the planning phase to .32 currently. Again, this is largely due to the current cost of construction and the reduction in buildings being included. Since we only have $2.5 million available from federal sources and $1 million in state LCCMR funds, we legally can no longer implement this project. We will be crossing budget thresholds. Only the design of the biomass facility has been completed.

PROJECT RESULTS USE AND DISSEMINATION
The funds spent for the Biomass project enabled the MNARNG to design a 5,000,000-BTU centralized biomass boiler system that was intended to heat 2 building on Camp Ripley. The design process started with 7 buildings but due to increase in material cost we had to decrease the scope to only 2 buildings.

The design is complete and on the shelf and available to others.

No information or the project design has been disseminated.

Project Completed: 12/31/2023
FINAL REPORT

Subd. 07e Geotargeted Distributed Clean Energy Initiative - $800,000 TF (FY2018)

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Appropriation Language
$800,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Center for Energy and Environment. Of this amount, $600,000 is for analysis of community-distributed clean energy investments as alternatives to utility capital investments for transmission and distribution upgrades to meet forecasted electrical loads, and $200,000 is to conduct pilot programs using energy efficiency and other distributed energy resources to achieve forecasted electric energy loads in communities. The appropriation for pilot programs is contingent on a $200,000 match of an equal or greater amount of nonstate money. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project demonstrated that energy efficiency can be used to reliably offset utility infrastructure expansion, thereby saving money and decreasing the amount of air pollutants from Minnesota's electricity generation.

OVERALL PROJECT OUTCOME AND RESULTS
This pilot project demonstrated that energy efficiency and demand response are cost-effective tools to increase the use of clean electricity technologies while reliably deferring investments in grid expansion. While Minnesota has relatively low distribution grid expenditures today, peak demand is predicted to increase due to population growth, electrification of end uses like transportation and space heating, and warmer temperatures. This pilot demonstrated that adopting longer time horizons and multiple scenarios for planning forecasts will allow distribution planners to integrate non-wires alternatives, therefore saving money and advancing clean energy throughout the state.

This pilot successfully saved 576 kW of peak electricity across two small communities, higher than the pilot goal of 500 kW. This was the result of enhanced incentives, increased and geotargeted marketing, as well as a higher than average baseline participation in commercial lighting programs. Participation was also boosted by smart thermostat incentives which were available upon enrollment in a demand management program. The pilot cost (incentives + direct labor) came to $163,000, within the estimated

value of a one-year deferral.

Minnesota has a modest technical potential for non-wires alternatives, but this is expected to increase. With current growth forecasts and distribution system expenditures, we calculated a low to modest potential for non-wires alternatives in Minnesota, estimated at between one and four million dollars per year. This will save between 4,000 and 17,000 tons of carbon per year, or the equivalent of the annual pollution caused by 800-6,000 passenger vehicles.

Additional information is included in the final technical report for this project on the CEE website.

PROJECT RESULTS USE AND DISSEMINATION
This pilot is summarized in a technical report and project summary document that outlines the process, major findings, and recommendations for policymakers and stakeholders. Results have been included in policy processes at the Public Utilities Commission to help inform regulatory decisions. Pilot outcomes have been presented at multiple conferences of industry professionals and to Minnesota utilities.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 08 Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Subd. 08a Optimizing the Nutrition of Roadside Plants for Pollinators - $815,000 TF (FY2018)

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Appropriation Language
$815,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with the Departments of Agriculture, Natural Resources, and Transportation and the Board of Water and Soil Resources to produce site-specific recommendations for roadside plantings in Minnesota to maximize the nutritional health of native bees and monarch butterflies that rely on roadside habitat corridors. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This research shows that, from a nutritional perspective, Minnesota roadsides are promising habitat for native bees and monarchs. To minimize the negative effects of roadside pollutants on insect pollinators, managers should prioritize low- to moderate-traffic roads for restoration, mow a buffer strip, and support efforts to ban the pesticide chlorpyrifos.

OVERALL PROJECT OUTCOME AND RESULTS

Insect pollinators have suffered steep declines over the last two decades. Roadsides are a promising opportunity for pollinator conservation, potentially providing millions of acres of habitat, and acting as dispersal corridors. However, roadside habitat also contains pollutants such as heavy metals from car wear and past leaded gasoline use, sodium from road salt application, and pesticides from adjacent agriculture. In this research, we combined surveys of roadsides across Minnesota, with controlled lab and field experiments, to test how such roadside pollution impacts insect pollinators, and implications for restoring roadside habitat for monarch butterflies and native bees. Our results suggest that plants alongside the majority of Minnesota roadsides have sodium and metal content below which is worrisome to bees and monarchs. However, plants along very high traffic roads, especially those right next to the road, likely have negative effects on pollinator health. Our data also suggest that pesticides may be a significant concern for 5-10% of roadside plants. This research suggests roadside restoration efforts should focus on roads with low to moderate traffic volumes (<20K cars daily) and that mowing a buffer on the road edge should eliminate the most toxic plants. Recent national efforts to ban the pesticide chlorpyrifos would also be beneficial for Minnesota roadsides as this was the most commonly detected insecticide. Finally, this research suggests benefits to planting a diversity of roadside plants as species accumulate different toxins to different degrees, although on higher traffic roads, managers may want to avoid a handful of high accumulating species (e.g., yellow coneflower). Overall, from a nutritional perspective, Minnesota roadsides are promising habitat for insect pollinators, for instance, potentially producing 14M migratory monarchs annually. Future work should consider management methods that may minimize vehicle collisions, as currently pollinator mortality from collisions likely far exceeds that from plant toxicity.

PROJECT RESULTS USE AND DISSEMINATION

This project directly led to six publications in print and twelve in progress. Data are publically available on either DRYAD or Mendeley. This work was presented in over 25 seminars, conference presentations, and webinars presented locally, nationally and internationally. The conclusions of the work are available in online talks, such as the Cedar Creek "Lunch with a Scientist" series and the Rights-of-Way working group research series on pollinator habitat. This research will be featured in a popular science book on road ecology and resulting management recommendations shared as a brief report to relevant agencies later this year.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 08c Evaluating the Use of Bison to Restore and Preserve Savanna Habitat – Research Project - $388,000 TF (FY2018)

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Appropriation Language
$388,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Cedar Creek Ecosystem Science Reserve, to research combined bison grazing and fire management strategies to restore Minnesota's oak savanna ecosystems. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Oak savanna is Minnesota's most threatened ecosystem, but effective approaches for protecting and restoring savannas remain elusive. Our project reintroduced bison to one of Minnesota's largest remaining oak savannas. We found that bison grazing helped increase oak regeneration and stimulated plant productivity, providing a promising new strategy for savanna conservation.

OVERALL PROJECT OUTCOME AND RESULTS
Oak savanna is Minnesota's most threatened ecosystem, but effective approaches for protecting and restoring savannas remain elusive and prescribed fire, alone, is not maintaining oak savannas. Fire helps old oaks with thick bark that can survive its intense heat, in part by preventing other trees from growing and shading the oaks. However, fire also kills young oak seedlings, which prevents oak trees from regenerating. Thus, fire is a necessary, but insufficient strategy for maintaining oak savannnas. We tested whether bison are essential for savanna preservation and restoration. Bison preferentially graze the most abundant native prairie grasses, which compete with young oaks and supply fuel for fires that kills them. Our project achieved the following outcomes: (1) discover better restoration and preservation practices for savanna remnants; (2) determine how these practices impact the full range of savanna biodiversity; and (3) educate Minnesotans about the ecological heritage of their state, including the roles that bison, fire and biodiversity play in the functioning of savannas and other Minnesota ecosystems. Specifically, we restored seasonal bison grazing to more than 200 acres of oak savanna, experimentally tested savannna restoration using bison grazing by establishing experimental plots and planting 660 oak seedlings, and disseminated results to more than 19,000 members of the public, in part by establishing a bison viewing gazebo. For many years to come, bison will continue to graze in these oak savannnas, their impacts will continue to be assessed in experimental plots, and the public will continue to benefit from site access and programming. Our project has already attracted additional funding from the National Science Foundation's Long-Term Ecological Research Program, which will allow it to continue long after the initial support from the ENRTF. Our data are being disseminated through Cedar Creek's website and the National Science Foundation's Environmental Data Initiative.

PROJECT RESULTS USE AND DISSEMINATION
We have provided engagement opportunities for more than 19,000 visitors, including 2,172 K-12 students who attended field trips or online programs specifically about this research. The new bison gazebo has provided opportunities for a corps of 25 “bison naturalist” volunteers, spurred the creation of new educational resources including a savanna-themed feltboard and brochures, hosted open house events and tours, led to the design and construction of two new interpretive signs, and expanded the range of self-guided options for our community.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 08d State Park Pollinator Habitat Restoration - $672,000 TF (FY2018)

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Appropriation Language
$672,000 the first year is from the trust fund to the commissioner of natural resources to restore at least 520 acres of monarch butterfly and other native pollinator habitats in at least seven state parks in the Minnesota Prairie Conservation Plan core areas and establish pollinator plantings and interpretive exhibits in at least ten state parks. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project restored approximately 520 acres of prairie/pollinator habitat in eight state parks where it will be permanently managed and protected. Additionally, educational pollinator plantings ranging in size from tenths of an acre to more than an acre were installed with engaging multi-sensory ADA-accessible interpretive exhibits at ten state parks.

OVERALL PROJECT OUTCOME AND RESULTS
Many species of pollinators are declining due primarily to habitat loss/degradation, diseases and parasites and pesticide exposure. This project focused on restoring 584 (520 originally planned) acres of prairie/pollinator habitat in eight state parks where it will be permanently managed and protected. Additionally, this project helped raise awareness about pollinators by establishing educational pollinator plantings from tenths of an acre to more than one acre in size with engaging multi-sensory ADA-accessible interpretive exhibits at 10 state parks.

Sites selected for habitat restorations were all within core areas identified in the Minnesota Prairie Conservation Plan. The sites themselves were former agricultural fields in state parks that contained non-native and invasive species. Site preparation included activities such as prescribed fire, control of invasive/problem species, woody stem removal, and disking. At Lake Bronson and Glacial Lakes State Parks, removal of encroached woody vegetation was the primary need to restore pollinator habitat through shearing/timber harvest. Following planting, sites were high mowed, spot treated for invasives and inter-seeded to ensure successful restorations. These sites will provide habitat for many species of pollinators such as bees, moths, and butterflies. For example, a recent study of prairie restorations at Glendalough State Park found more than 25 species of butterflies utilizing the restorations, including the Regal Fritillary, a Minnesota Special Concern Species. This project will also assist in meeting the goals of the Mid-America Monarch Conservation Strategy.

Educational pollinator plantings and exhibits were installed at 10 state parks within all but the Laurentian Mixed Forest Province. Interpretive exhibits were designed and constructed in cooperation with an exhibit contractor. Where needed educational plantings were established similar to the steps above albeit on a much smaller scale. Annual visitation at these 10 parks combined totals over three million visits annually.

PROJECT RESULTS USE AND DISSEMINATION
Educational pollinator plantings and exhibits provide an opportunity for millions of visitors annually to learn more about pollinators and the plant species which attract them. Attendance at these 10 parks combined is over three million visitors per year. The exhibits are regularly used by thousands of visitors per week based on park attendance and staff reports.

- The exhibit design was entered in the National Association of Interpretive Naturalists 2021 Media Awards competition and earned first place in the Outdoor Exhibits category. The award presentation was broadcast to over 800 interpretive professionals in December of 2021
- In summers of 2020 and 2021 this project was highlighted on the DNR Parks and Trails social media platforms as part of a monthly theme on butterflies. The 2021 campaign reached 33K Twitter followers and 151K Facebook followers.

Project Completed: 06/30/2022
FINAL REPORT

Subd. 08e Enhancing Spawning Habitat Restoration in Minnesota Lakes – Research Project - $294,000 TF (FY2018)

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Appropriation Language
$294,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, St. Anthony Falls Laboratory, in cooperation with the Department of Natural Resources to enhance efforts to increase natural reproduction of fish in Minnesota lakes by assessing wave energy impacts on near-shore spawning habitat. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The main goal of this project was to create easily accessible information on wave energy to enable successful habitat restoration projects and increase natural fish reproduction in Minnesota lakes. We created maps, in GIS format, of wave height and energy statistics for 457 lakes in Minnesota.

OVERALL PROJECT OUTCOME AND RESULTS
There are many ways in which healthy near-shore habitat and water quality in lakes is linked to wind and wave energy. Examples include walleye spawning habitat on nearshore gravel substrates, the distribution of submersed aquatic plants, sediment resuspension by wave action, and shoreline erosion. Successful lake habitat restoration requires good information on wind and wave energy, and this

information is commonly not available. The main goal of this project was to create easily accessible information on lake wave energy to enable successful habitat restoration projects and increase natural fish reproduction in Minnesota lakes. The project partnered the University of Minnesota with the MN DNR and included field measurements of wind and wave height on four lakes ranging in size from 350 to 5000 acres, wave modeling work to map typical wave energy on the shorelines of 457 Minnesota lakes, and experimental work in a wave flume to better understand how nearshore sediment responds to wave energy in lakes. A major part of the project was to develop models for wave height and energy that consider wind sheltering by trees, so that wave height predictions could be made for smaller lakes with fetches of a kilometer or less. The wave maps created by this study can be used by state agencies and lake associations to plan lake shoreline management, including habitat restoration projects, aquatic plant management, and shoreline erosion control.

PROJECT RESULTS USE AND DISSEMINATION
Electronic maps of wave height and energy created in this project will be uploaded to the Data Repository for University of Minnesota (DRUM), and details of the project will be published in a St. Anthony Falls Lab project report to document the methodologies used. The project PI gave a talk on the project at a conference on Sentinel lakes in March 2019 in Alexandria, MN, and is giving a poster presentation at the 2021 Minnesota Water Resources Conference.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 08f Prescribed Fire Management for Roadside Prairies - $345,000 TF (FY2018)

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Appropriation Language
$345,000 the first year is from the trust fund to the commissioner of transportation to enhance the prescribed-fire program to manage roadsides to protect and increase biodiversity and pollinator habitat. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
MnDOT's fire program has grown exponentially since this funding was secured. All fire crews have gained extensive experience and have gained a lot of confidence on how and when fire should safely be used. The number of areas and districts in which fire occurs on MnDOT property has increased throughout this project. Within the next 5 years MnDOT will be conducting prescribed fire in 6 of its 8 districts around the state.

OVERALL PROJECT OUTCOME AND RESULTS
MnDOT fire program took major steps forward with this funding and has secured a self-sustaining fire

program. Prior to this funding DOT completed less than 5 burns a year, in the 3 years of this program DOT completed 78 burns that totaled 142 miles of ROW burned totaling 1,600 acres of Mn and US highway ROW burned statewide. Even with one years of no burning allowed due to COVID 19, we surpassed our goals of this project and doubled our acres completed. DOT's current burn program has changed how native planting will be installed in the future, by being able to help maintain them for long lasting success. More Roadside Rest Areas around the state will be planted with native vegetation, to help increase pollinator habitat and reduce maintenance cost associated with turf grass. Six MnDOT staff have received fire training on becoming burn bosses, with one person finishing all training and task books required. With additional staff able to complete burns, MnDOT's fire program will continue to grow and expand.

PROJECT RESULTS USE AND DISSEMINATION
A Master Partnership Agreement was drafted, completed, and currently in place which allows MnDOT to assist the MnDNR on all aspects of wildfire suppression and prescribed fire operations, this agreement includes funding for direct payment between the two state agencies. With MnDOT assisting the DNR in wildfire suppression, it is our hope that we will reduce the number of resources needed from other state agencies and contractors.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 08g Minnesota Bee and Beneficial Species Habitat Restoration - $732,000 TF (FY2018)

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Appropriation Language
$732,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Pheasants Forever in cooperation with the University of Minnesota and the Minnesota Honey Producers Association to restore approximately 800 acres of permanently protected land to enhance bee, butterfly, beneficial insect, and grassland bird habitats. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project's goal was to enhance and study 800 acres of permanently protected habitat by converting low diversity grassland areas to high diversity native grasses and wildflowers. The result of our efforts was the successful enhancement of 1,949.69 acres of habitat to benefit pollinators and other wildlife.

OVERALL PROJECT OUTCOME AND RESULTS
Grassland habitat loss and fragmentation continue to be the major factor in the decline of monarchs, other pollinators and grassland wildlife. While we have restored hundreds of thousands of acres of

grasslands, our early restorations rarely considered the needs of pollinators, the value of milkweed species to the monarch, or the vegetative structural and species diversity required by many species.

This project sought to address the loss of habitat essential to pollinators by enhancing 800 acres of low diversity grasslands on permanently protected lands. These enhancements were monitored in collaboration with the University of Minnesota (UofM) to, inform practitioners of best practices and provide a path to future habitat enhancements for native pollinators.

Enhancement projects were solicited by Pheasants Forever (PF) and project partners through a sign-up period via an RFP sent to SWCD's and other private land partners in the agricultural region of Minnesota. Application were ranked and funded based on potential benefit to the program. Private contractors were hired by PF to complete enhancement work on 1949.69 acres. After enhancement work was completed researchers from the UofM monitored the sites to measure usage by pollinator species as well as measure native plant growth.

Pollinators are extremely important to the production of foods and other products that Minnesotans utilize, as well as other ecosystem services. Whether through funding or policy, the decline of pollinators suggests the need to put a greater emphasis on the protection, restoration, and management of their habitats. Once results are analyzed, the research conducted by the UofM will help improve our best management practices in pollinator habitat restoration and enhancement.

PROJECT RESULTS USE AND DISSEMINATION
The enhancement activities completed by this project did not result in the creation of any new tools or documents. Projects were occasionally highlighted in field tours, or via social media posts. The field research conducted by the UofM is now complete, but data analysis and results have yet to be finalized or published. Once complete, this data will be available to the public and should inform practitioners about improved methods for restoring and enhancing pollinator habitat.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 08h Mississippi and Vermillion River Restoration of Prairie, Savanna, and Forest Habitat – Phase Ten - $213,000 TF (FY2018)

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Appropriation Language
$213,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Friends of the Mississippi River for continued implementation of the Metro Conservation Corridors partnership by improving at least 80 acres of habitat at approximately seven sites along the Mississippi

River and Vermillion River corridors. Expenditures are limited to the identified project corridor areas as defined in the work plan. A list of proposed restoration sites must be provided as part of the required work plan. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Friends of the Mississippi River increased and improved 133 acres of habitat at 6 sites along the Mississippi and Vermillion River corridors, linking existing nodes of high biodiversity. The project restored and enhanced prairie, savanna and forest habitat along the river corridors with a focus on increasing habitat for pollinators.

OVERALL PROJECT OUTCOME AND RESULTS

Through this project, Friends of the Mississippi River will increase and improve 82 acres of habitat at 7 sites along the Mississippi and Vermillion River corridors. Habitat fragmentation and degradation from non-native species, diseases and other causes threaten Minnesota's rich natural heritage. This situation will be exacerbated as the state's climate continues to change. A system of interconnected natural areas can help to lessen these impacts by providing both habitat and the ability for native species to move on the landscape in response to these changes. This is the goal of the Metro Conservation Corridors partnership and of this proposal. The projects on our list are all along the Mississippi and Vermillion Rivers, natural corridors that link the existing nodes of high biodiversity.

The overarching goal for this project is to restore and enhance prairie, savanna, and forest habitat along these river corridors. While these projects will improve habitat for a variety of species, FMR will specifically focus on increasing habitat for our diminishing pollinators. We will seed and install a diversity of host and nectar plants. The restoration activities, presented in existing natural resource management plans, include exotic invasive plant removal, soil preparation, spraying, seeding, mowing, plant installation and burning. To help reduce costs and to increase the educational outcomes, FMR will organize volunteer stewardship events to accomplish some of the restoration activities at some of these sites. These restoration activities will have multiple benefits. An important outcome will be to improve or increase habitat for native pollinators by increasing host and nectar plants. Seed mixes will exceed the Minnesota Board of Soil and Water guidelines, with many additional pollinator plant blooms in all seasons. Restoration activities at these sites will provide water quality benefits by installing deep-rooted prairie/savanna plants that help reduce erosion and sediment & chemicals from entering the rivers. Being within the Metro area, these sites provide examples of diverse native habitat for area residents to enjoy and learn about. A final goal of this project is to work with Metro Conservation Corridors partners to develop a more uniform restoration monitoring and evaluation protocol that also allows the data to be shared. Each of the specific sites in this project is in public ownership and have natural resource management plans in place to guide the habitat restoration and management activities and are on file at FMR. The Conservation Corps of Minnesota is on our contractor contact list and receive notice for all restoration Request for Proposals that we prepare and distribute.

FMR will conduct an evaluation for each of site upon completion of these grant-funded restoration activities and three years later. These evaluations will analyze how the activities achieved the goals for the project, present any unforeseen issues that impacted the achievement of those goals and lessons learned from the project.

PROJECT RESULTS USE AND DISSEMINATION
FMR promoted and disseminated information about this project through earned media, FMR's website (www.FMR.org), electronic & printed newsletters, and volunteer stewardship events. FMR has acknowledged ENRTF in all publications and events that refer to these projects. FMR will work with landowners to erect signage where ENRTF grant funds were spent.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 08i Community Stewardship to Restore Urban Natural Resources - Phase Ten - $524,000 TF (FY2018)

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Appropriation Language
$524,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Great River Greening to work with volunteers for continued implementation of the Metro Conservation Corridors partnership to restore approximately 250 acres of forest, prairie, woodland, wetland, and shoreline throughout the greater Twin Cities metropolitan area. Expenditures are limited to the identified project corridor areas as defined in the work plan. A list of proposed restoration sites and evaluations must be provided as part of the required work plan. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
To protect Minnesota's natural heritage, Greening restored and enhanced 310 ecologically significant acres in priority metro areas and engaged volunteers in a suite of activities to address the need for long-term management of projects. Greening disseminated results for the layperson through electronic channels and to professionals through a published paper.

OVERALL PROJECT OUTCOME AND RESULTS
We reached 123% of our acreage goals, restoring and enhancing 310 acres of significant ecological habitat, compared to the 252 acres anticipated. The 12 restoration and enhancement sites were selected based on ecological significance and potential for improvement. Restoration and enhancement improvements were made on prairie, forest, and wetland communities including habitat for rare species, within the mapped Metro Conservation Corridors.

We successfully engaged 468 volunteers in hands-on restoration, and 5 known observers via iNaturalist

app for a combined total of 473 contacts. Reaching this number was a challenge we met, as during the second half of this appropriation, we had to significantly and rapidly modify our community outreach and event models in response to the COVID-19 pandemic to safely engage our volunteers throughout 2020 and 2021. We were successful in our community engagement events with staggered start time, multi-shift days with smaller pods of volunteers, and strict safety guidelines in place. Furthermore, we also piloted independent volunteer outings utilizing the iNaturalist platform, allowing volunteers to explore project parcels and record their observations independently. These observations provided very useful data (e.g. benchmarking progress and identifying patches of exotic species) while engaging volunteers in a novel way.

To help address the need for innovative methods for long term maintenance, we also offered two additional levels of volunteer engagement beyond field volunteer and started using a digitized restoration evaluation for more standard, shareable data. The 'site monitor' level of engagement was successful, but the 'site steward' level of engagement was challenging due to a combination of the pandemic, and the effort needed to get landowners, GRG, and volunteers comfortable with making independent enhancement decisions.

PROJECT RESULTS USE AND DISSEMINATION
Greening highlighted projects over a suite of social media (twitter, Facebook), website, and external media. Examples from the final months of the appropriation include: May 2021 feature on our work at Inspiration easement; Oheyawahe/Pilot Knob Hill site highlighted during a March 2021 segment on KARE 11, then shared in Greening channels; the Blaine Wetland Sanctuary enhancement featured in our June 2021 Greening channels.

A peer-reviewed paper on the pollinator response to conservation haying and burning treatments at Six Mile Marsh authored by members of each stakeholder organization has recently been accepted for publication in 2021.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 08j Economic Assessment of Precision Conservation and Agriculture - $400,000 TF (FY2018)

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Appropriation Language
$400,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Pheasants Forever to demonstrate a new approach to promote conservation practices utilizing return-on-investment analysis and identifying revenue-negative acres on agricultural land to assist farmers in implementing conservation practices that will provide environmental and economic benefits.

This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project showcased opportunities available for farmers and landowners to implement profitable conservation practices on lands otherwise providing a negative return. Through this new approach to conservation delivery, we were able to put 1,216 acres of conservation on the landscape, providing multiple benefits to Minnesota's natural resources and economy.

OVERALL PROJECT OUTCOME AND RESULTS
With recent advancements of real-time yield monitoring, it has been demonstrated that, on many farms, 3-15% of cropped acres cost money to farm (revenue negative acres). By applying the current cutting-edge precision technology and focusing on return on investment (ROI) to deliver conservation, we worked with farmers to identify areas that make sense for them to apply conservation practices in a practical and profitable way. This new approach to conservation delivery, focused on revenue negative acres, provided insight to the consideration of profitable conservation practices, reasons for conservation adoption, and the delivery of conservation acres that otherwise would've continued to be in traditional crop production. In addition, this project demonstrated a high level of cooperation and coordination between agriculture and conservation.

By looking at the entire operation, at the enterprise level, current technology allows for acre-by-acre analysis to develop conservation solutions on acres that otherwise yield a negative return. This project worked directly with 72 farmers to analyze 45,214 acres and look for conservation solutions on 5,382 acres that are low yielding in comparison to the rest of the field or operation. Our findings show that of the analyzed acres, 12% of the acres fell below break-even yield, which is in the range of 3-15% revenue negative acres demonstrated by previous research (E Brand et al 2016). With the analysis and available program opportunities this project was able to meet farmer objectives while increasing profitability through conservation on 1,216 acres. These are acres that otherwise didn't receive consideration for conservation practices. While not all identified acres received immediate change, the overall conversation and influence of this project, opened the door for continued conservation consideration and future conservation adoption. The practices implemented provide direct benefit to Minnesotans through increased soil health, water quality, carbon sequestration, wildlife habitat, and other natural resources.

PROJECT RESULTS USE AND DISSEMINATION
This project resulted in the hiring of a precision ag & conservation specialist to work with farmers, landowners, trusted advisors and demonstrate the use of precision agriculture technology to deliver conservation on the landscape. This project helped launch the addition of multiple staff in additional states to both implement and influence conservation on the landscape. This project hosted or was a part of 66 different outreach event impacting 3,608 attendees. Outreach consisted of online webinars, attendance at tradeshows (such as the MN Ag Expo and FarmFest) along with varying presentations and meetings geared towards ag professionals, conservation professionals, and farmers/landowners.

Project Completed: 06/30/2022
FINAL REPORT

Subd. 09 Land Acquisition, Habitat and Recreation

Subd. 09a Metropolitan Regional Parks System Land Acquisition - $1,500,000 TF (FY2018)

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Appropriation Language
$1,500,000 the first year is from the trust fund to the Metropolitan Council for grants to acquire approximately 197 acres of land within the approved park boundaries of the metropolitan regional park system. This appropriation may not be used to purchase habitable residential structures. A list of proposed fee title acquisitions must be provided as part of the required work plan. This appropriation must be matched by at least 40 percent of nonstate money that must be committed by December 31, 2017. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The Metropolitan Council along with Washington County and Carver County acquired 12 parcels to increase recreational opportunities for the Regional Parks System. These critical acquisitions protected over three miles of Minnesota River and St. Croix River shoreline and 192 acres of high-quality natural resource land in Washington and Carver Counties.

OVERALL PROJECT OUTCOME AND RESULTS
The Metropolitan Council works with the Regional Park Implementing Agencies to protect critical lands and provide recreational opportunities for the Regional Parks System. This $1,436,000 ENRTF project was matched with $1.7 million in Council funds and Agency funds to purchase 14 parcels for the Regional Parks System.

Washington County acquired a 102-acre property for St. Croix Bluffs Regional Park with funding from this and a previous appropriation. The property contains critical habitats including hardwoods, mixed forest, open meadow, and 3,800 feet of St. Croix River shoreline. With the addition of this 102-acre parcel, the park now protects 5,000 contiguous feet of shoreline. Carver County acquired 13 parcels for the Minnesota River Bluffs Regional Trail, protecting 90 acres of natural resources and 3 miles of regional trail, much of it along the Minnesota River corridor.

Acquiring these properties permanently protects critical natural resources while providing additional recreational opportunities for the region. All properties funded are inholdings or parcels that are included in master plan-approved park boundaries. The Regional Park Implementing Agencies work only with willing landowners when acquiring lands with ENRTF, and they focus on acquiring lands with high natural resources and habitat value that are at risk of being developed.

PROJECT RESULTS USE AND DISSEMINATION
Articles were released both after the grant was awarded and after the Rowe parcel was purchased for

Washington County's St. Croix Bluffs Regional Park, including an article in the Pioneer Press on June 11, 2019. Carver County celebrated the opening of their rebuilt portion of the Minnesota River Bluffs Regional Trail on July 13, 2021 with a public celebration. Several news releases were published, including the SW News Media and on Carver County's website. The Council also issued news releases after each grant was awarded. The Agencies include the ENRTF sign when they install visitor signs. In addition, the Metropolitan Council and the Agencies acknowledge ENRTF for any media releases about the acquisitions.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 09b Scientific and Natural Areas Acquisition, Restoration, Citizen Science and Engagement - $2,500,000 TF (FY2018)

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Appropriation Language
$2,500,000 the first year is from the trust fund to the commissioner of natural resources to acquire at least 250 acres of land with high-quality native plant communities and rare features to be established as scientific and natural areas as provided in Minnesota Statutes, section 86A.05, subdivision 5, restore and improve at least 1,000 acres of scientific and natural areas, and provide technical assistance and outreach, including site steward events. At least one-third of the appropriation must be spent on restoration activities. A list of proposed acquisitions and restorations must be provided as part of the required work plan. Land acquired with this appropriation must be sufficiently improved to meet at least minimum management standards, as determined by the commissioner of natural resources. When feasible, consideration must be given to accommodate trails on lands acquired. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Volunteers, staff, and contractors with Minnesota DNR completed enhancement and improvement activities on almost two-thousand acres of quality habitat on 75 of Minnesota's SNAs. A 10-acre wetland acquisition was added to Hastings SNA. Many thousands more people learned about, visited, or helped steward an SNA thanks to this funding.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota's Scientific and Natural Areas (SNAs) are public lands representing the state's best hope for protecting rare features and averting biodiversity loss. This appropriation strengthened the "science" in

SNA through monitoring-based habitat enhancement, citizen-science action and outreach, and strategic acquisition to protect additional high-quality natural lands. Over 1,930 acres across 75 SNAs were treated for terrestrial invasive species, received much-needed prescribed disturbance (e.g., prescribed fire, haying, etc.) or received other site improvement work, to maintain the overall quality of natural habitats for the rare and unique species that call these lands home. Such habitat work was guided by monitoring and site-assessment efforts taken on by staff as well as by volunteers: at least 190 SNA stewardship or interpretive events were held with an estimated attendance of nearly 6,000 participant volunteers donating thousands of hours to the educational, citizen-science, and stewardship aims of the SNA Program, led in part by the network of long-term volunteer Site Stewards serving at almost all SNAs by caring for the land and reporting observations. Online users observed upgrades to each SNA's webpage with improved interpretive narrative and consistent, unified themes; likewise, enhanced SNA social media presence and content have dramatically ramped up followers, subscribers, and forum membership numbers since this funding began, extending the reach and audience of the SNA Program on a variety of platforms to enhance public support for conservation. The project permanently protected a new tract consisting of 10 acres of high-quality wetland as an addition to Hastings SNA near the confluence of the Vermillion and Mississippi Rivers, important for water quality and for many special-concern and migratory bird species in the Mississippi flyway. Through this appropriation's support for programmatic acquisition work, around ten other SNA acquisition projects were recruited and developed, though several of these have proceeded instead on alternative funding.

PROJECT RESULTS USE AND DISSEMINATION

The SNA website is updated regularly, e.g., with improved species lists from monitoring efforts or for new or expanded SNAs, and with a frequently updated events calendar now also appearing in the "LCCMR Updates" e-newsletters. The 46th (Summer 2022) issue of the SNA Nature Notes e-newsletter was delivered to 10,790 subscribers (more than double since this appropriation began). The SNA Facebook channel now has ~9.1K followers, and the SNA Program contributes twice-monthly content to the DNR Instagram channel. The Minnesota SNAs Flickr group has 108 members currently sharing over 1,500 high-quality photos of the beauty and diversity of Minnesota's SNAs.

Project Completed: 06/30/2022
FINAL REPORT

Subd. 09d Minnesota State Trails Acquisition, Development and Enhancement - $1,038,000 TF (FY2017 - $999,000 / FY2018 - $39,000)

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Appropriation Language
$999,000 in fiscal year 2017 and $39,000 the first year are from the trust fund to the commissioner of natural resources for state trail acquisition, development, and enhancement in southern Minnesota. A proposed list of trail projects on authorized state trails must be provided as part of the required work plan. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project focused on expanding recreational opportunities and enhancing user safety on Minnesota's State Trails through the development of two new State Trail Segments, (1) the Casey Jones State Trail – Woodstock Segment, Pipestone County and (2) the Mill Towns State Trail – Cannon River Bridge and Trail Connection, Rice County.

OVERALL PROJECT OUTCOME AND RESULTS
As of June 30, 2020 the Minnesota Department of Natural Resources had completed the development of the two proposed new State Trail Segments, the Woodstock Segment of the Casey Jones State Trail near the community of Woodstock, Pipestone County and the new Mill Towns State Trail - Cannon River Trail Bridge and Trail in the City of Faribault, Rice County. Department of Natural Resources Engineering Staff completed all engineering and design required for the development of the two discrete trail segments and administered the associated construction contracts. All of the new State Trail infrastructure has been designed to meet the applicable requirements of the Americans with Disabilities Act (ADA) as well as trail design guidelines developed by Minnesota Department of Natural Resources and the Minnesota Department of Transportation. Although the Casey Jones State Trail Segment as originally proposed was to include the upgrading and bituminous surfacing of approximately 5 miles of the existing State Trail corridor, the project had to be revised when realized construction costs substantially exceeded the pre-design cost estimates. As revised, the Casey Jones State Trail Project consisted of the upgrading and improvement of the entire 5 miles of the existing State owned former railroad grade as originally proposed, however, the bituminous trail surfacing was limited to approximately 3 miles. The development of the new Mill Towns State Trail Cannon River Bridge and Trail has provided both the intended connection between the Mill Towns State Trail, the Sakatah-Singing Hills State Trail and the local trail system and a significant improvement in user safety realized through the elimination of the previously required "at-grade" crossing of TH21 at the Cannon River. Both of the new State Trail segments were substantially complete in 2019 and immediately opened to public use. Final project closeout was complete for both projects in late 2020.

PROJECT RESULTS USE AND DISSEMINATION
The Project's two Minnesota State Trail improvement and enhancement projects , the Casey Jones State Trail – Woodstock Segment and the Mill Towns State Trail – Faribault Canon River Bridge Crossing were completed through the collaborative and cooperative efforts of the Communities of Woodstock and Faribault, Pipestone County, the Friends of the Casey Jones Trail Association and the Mill Towns Trail Association. The Minnesota Department of Transportation's direct participation was also critical in the project's success. The project plans and specifications for each project were subject to review and approval by all project partners prior to implementation. Each of the project partners played a critical role in disseminating project information during both the design and construction phases of the projects. Following substantial completion of the Mill Towns State Trail – Cannon River Bridge and Trail Segment in Late 2019, the City of Faribault hosted a "Grand Opening and Ribbon Cutting". This event was held at the adjacent White Sands Trailhead, a municipally developed facility, and was well attended by members of the public and local dignitaries. Each of the communities and trail groups involved in

these projects remain active in advocating for further expansion and improvement of both the Casey Jones and Mill Towns State Trails. Each of the State Trail Maps published by the DNR have been updated to reflect the completed projects. The Environment and Natural Resources Trust Fund is acknowledged as a Project Partner on the Casey Jones Trailhead Sign in Pipestone and will be acknowledged with a sign that is to be affixed to the Mill Towns State Trail - Cannon River Bridge.

Project Completed: 06/30/2020
FINAL REPORT

Subd. 09e Native Prairie Stewardship and Prairie Bank Easement Acquisition - $2,675,000 TF (FY2018)

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Appropriation Language
$2,675,000 the first year is from the trust fund to the commissioner of natural resources to acquire native prairie bank easements in accordance with Minnesota Statutes, section 84.96, on approximately 335 acres, prepare baseline property assessments, restore and enhance at least 570 acres of native prairie sites, and provide technical assistance to landowners. Of this amount, up to $132,000 may be deposited in a conservation easement stewardship account. Deposits into the conservation easement stewardship account must be made upon closing on conservation easements or at a time otherwise approved in the work plan. A list of proposed easement acquisitions must be provided as part of the required work plan. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Permanently protected 287 acres of high-quality historically undisturbed native prairie, which house state threatened and special concerns species, Species in Greatest Conservation Need and a wide variety of pollinators. Prairie enhancement (1,227 acres), outreach, monitoring and research activities were implemented across the state to improve prairie habitat.

OVERALL PROJECT OUTCOME AND RESULTS
Through this appropriation, 287 acres of high-quality native prairie, which house state threatened and special concerns species, Species in Greatest Conservation Need and a wide variety of pollinators, were permanently protected through 5 Native Prairie Bank conservation easements (see attached parcel list). Protection efforts, through this appropriation and others, preserve some of the best remaining native prairie in the state for current and future Minnesota Citizens benefit. These remaining native prairies function at a significantly higher level and provide habitat to more species of insects, birds, reptiles, and mammals than restored prairie. Additionally, 21 Baseline Property Reports and 53 monitoring events

were completed and stewardship funds for the 5 closed Native Prairie Bank easements were enrolled into the Conservation Easement Stewardship Account.

A total of 705 acres of invasive species control and 522 acres of prescribed disturbance were completed to improve prairie quality throughout the prairie region of the state. Adaptive Management Monitoring was completed on 50 Native Prairie Banks. Knowledge gained through this monitoring and research will help landowners, DNR land managers and partner agencies improve the management of native prairie and wetlands.

DNR Prairie Specialists participated in 8 outreach events and engaged over 215 different priority prairie landowners on prairie protection, restoration, and enhancement. Prairie Stewardship Plans were completed for 14 landowners providing site specific management recommendations. The "Prairies of Minnesota Landowner Handbook" was published in June of 2021. To-date 3,500 copies of the book have been distributed to landowners and conservation professionals. A digital version of the book can be found on the DNR website.

Throughout this appropriation many challenges were encountered. A decrease in payment rates caused a higher decline rate, more time needed by landowners to decide on enrollment and the need for increased staffing to accomplish acquisition goals. This did allow for the acquisition of more acres for less and the return of a significant amount of money to the Commission for use on other great conservation projects. A pandemic froze or limited the ability to do many tasks, but staff got creative and looked for alternative approaches to get the work done.

PROJECT RESULTS USE AND DISSEMINATION
Fourteen Prairie Stewardship Plans were provided to native prairie landowners. These plans will guide the landowner's enhancement activities for well over a decade. The "Prairies of Minnesota Landowner Handbook" was published in June of 2021. To-date 3,500 copies of the book have been distributed to landowners and conservation professionals (who will continue to give the book to landowners managing prairies for years to come). A digital version of the book can be found here: https://files.dnr.state.mn.us/assistance/backyard/prairierestoration/prairie-handbook.pdf

All outreach materials produced through this appropriation followed ENRTF acknowledgement guidelines. Special thanks was given to ENRTF in the back cover of the book.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 09f Leech Lake Acquisition - $1,500,000 TF (FY2018)

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Appropriation Language
$1,500,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Leech Lake Band of Ojibwe to acquire approximately 45 acres, including 0.67 miles of shoreline of high-quality aquatic and wildlife habitat at the historic meeting place between Henry Schoolcraft and the Anishinabe people. The land must be open to public use including hunting and fishing. The band must provide a commitment that land will not be put in a federal trust through the Bureau of Indian Affairs.

Project Completed: 08/30/2018
FINAL REPORT

Subd. 09g Mesabi Trail Development - $2,269,000 TF (FY2018)

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Appropriation Language
$2,269,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the St. Louis and Lake Counties Regional Railroad Authority for engineering and constructing segments of the Mesabi Trail. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

Project due to be completed: 12/31/2022
FINAL REPORT
