M.L. 2018 Projects

MN Laws 2018, Chapter 214, Article 4, Section 2 (beginning July 1, 2018)

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Subd. 03 Foundational Natural Resource Data and Information

Subd. 03b Providing Critical Water-Quality Information for Lake Management - $250,000 TF

Jeffrey Peterson
U of MN
1985 Buford Ave, 173 McNeal Hall
St. Paul, MN 55108

Phone: (612) 624-9282
Email: jmpeter@umn.edu
Web: https://www.wrc.umn.edu/

Appropriation Language
$250,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a semiautomated system to acquire, process, and deliver new satellite-derived water-quality data in near real time on water clarity, algae, and turbidity for Minnesota lakes. 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 created an automated system, which is capable of delivering satellite derived near real-time data and maps of key water quality measures (chlorophyll, clarity, CDOM), and updated the Minnesota LakeBrowser with new data and capabilities to visualize the water quality of all Minnesota lakes to improve data-driven resource management.

OVERALL PROJECT OUTCOME AND RESULTS
Using satellite imagery, we have been assessing lake water quality in Minnesota for over 20 years. For early assessments, we used analyst directed image processing techniques using remote sensing software and empirically calibrated each satellite overpass with in situ water clarity data. These assessments were at around five year intervals due to the effort required and availability of clear satellite imagery. Recent advances in satellite technology (improved spectral, spatial, radiometric and temporal resolution) and atmospheric correction, along with cloud and supercomputing capabilities have enabled the use of satellite data for automated regional scale measurements of water resource characteristics. These new capabilities provide opportunities to improve lake and fisheries management by measuring more variables (chlorophyll, colored dissolved organic matter (CDOM) and total suspended matter, the main determinants of water clarity) more often.

To utilize these capabilities this project developed field-validated methods and implemented them in an automated water quality monitoring system on University supercomputers. The system acquires satellite imagery, removes clouds, cloud shadows, haze, smoke, and land, and applies water quality models to deliver satellite-derived water quality products. Using this system we created statewide

monthly open water (May through October) pixel level mosaics and lake level data for each clear image occurrence. The lake level (2017-2020) data included 603,678 lake measurements of chlorophyll, clarity and CDOM (1,811,034 total) that were compiled into a database that was used to calculate water quality variables for different timeframes (e.g. monthly, summer (June-Sept)) and linked to a lake polygon layer that was used for geospatial analysis and included in a web map interface. The Minnesota LakeBrowser was updated with monthly chlorophyll, clarity and CDOM data from 2017 to 2020 and new capabilities for citizens, resource managers and researcher to easily access the data for specific lakes and regions.

PROJECT RESULTS USE AND DISSEMINATION
Communication of project results used a range of outlets. The primary mode of dissemination is the update and expanded Minnesota LakeBrowser. This website provides content for diverse users including citizen scientists, lake users, homeowners, classrooms, natural resource managers, researchers at agencies and academic institutions. The updates improved search and allow visualization of long term (1975-2020) and seasonal (May-October) trends for individual lakes in graphs, and for individual lakes or regions in pixel or lake level maps. Results were also disseminated through social media and in presentations made at conferences and state agencies and will be disseminated in peer reviewed literature.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03c Minnesota Biodiversity Atlas - Phase 2 - $350,000 TF

George Weiblen
U of MN - Bell Museum of Natural History
10 Church St SE
Minneapolis, MN 55455

Phone: (612) 624-3461
Email: gweiblen@umn.edu
Web: www.bellmuseum.umn.edu

Appropriation Language
$350,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to expand the biodiversity atlas project by adding more than 800,000 records and images of Minnesota wildlife, plants, and fungi, including observations from state agencies and other museum collections, to enhance research, guide field surveys, and inform conservation planning. 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 Minnesota Biodiversity Atlas provides online access to 150 years' of natural history information by integrating and disseminating data from state agencies, museums, colleges, and universities. It enables the general public, natural resource managers, educators' and researchers to investigate past and present biodiversity patterns and make predictions about future directions.

OVERALL PROJECT OUTCOME AND RESULTS

This project expanded an online natural resource database situated at the University of Minnesota's Bell Museum to include data from multiple state agencies and museum collections. Extensive records of Minnesota biodiversity, past and present, are the product of ongoing biological surveys by agencies and organizations beginning with the Public Land Survey in 1848. As the official state museum of natural history, the Bell Museum is responsible for preserving and making available records of Minnesota plant and animal life. These records are the bellwether of informed responses to environmental change but literally millions of data points remain scattered among state agencies, museum collections and academic institutions.

The Minnesota Biodiversity Atlas serves to integrate and disseminate biodiversity data online. This second phase II of this project increased the size of the Atlas from 640,000 to 1,585,000 records of mammals, birds, fish, amphibians, reptiles, crustaceans, invertebrates, plants, and fungi. Additions included expert observations from the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency and also specimen records from the University of Minnesota Duluth, the Science Museum of Minnesota, the College of St. Benedict's/St. John's University, and Minnesota State University, Mankato.

Understanding biodiversity change in Minnesota and adapting to it are essential for cultural, economic, and environmental health. The Minnesota Biodiversity Atlas provides the historical baseline against which contemporary observations are compared to manage our natural heritage today and into the future. The Atlas is used by natural resource professionals, educators, and the public for species identification, distribution mapping, habitat assessment, restoration planning, management decision making, and learning. During the project, the Atlas grew to 500,000 digital images and 1.4 million mapped records. Software development needs for a mobile phone-friendly version of the Atlas were also identified.

PROJECT RESULTS USE AND DISSEMINATION

Online retrieval of data from the Minnesota Biodiversity Atlas grew from 76,000 page views in 2018 to 307,000 in 2021. Visitors to the Bell Museum also learn about the Biodiversity Atlas in the Minnesota Journeys gallery and it featured in a traveling exhibit that received over 70,000 in-person visitors. Two training workshops in using the Atlas were offered to over 30 natural resource professionals from across the state. In local media, it was twice featured on the "Grow with KARE" segment on channel 11 and in the Minnesota Daily.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 03d Peatland Forest Management - $600,000 TF

Marcella Windmuller-Campione
U of MN
1530 Cleveland Ave N, 115 Green Hall
St. Paul, MN 55108

Phone: (847) 772-5458

Email: mwind@umn.edu
Web: https://www.forestry.umn.edu/marcella-windmuller-campione

Appropriation Language
$600,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to identify management actions to maximize benefits to wildlife, water quality, timber production, and native plant communities in peatland forests. 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
This project monitored 48 peatland sites for four years providing critical new information on hydrology during wet and dry years, boreal chickadee breeding habitats (some of the first data of its kind), and plant diversity. Data show regeneration harvests do not significantly impact the water table and vegetation responds quickly.

OVERALL PROJECT OUTCOME AND RESULTS
Peatlands provide critical ecosystem services for Minnesotans, which include helping to maintain clean drinking water, providing important forest products, serving as critical habitat for many wildlife species including the boreal chickadee, and storing huge amounts of carbon. However, these are very understudied systems and climate change and other forest health threats are impacting peatland forests. Over a four year period, we've monitored 48 sites that span four different age classes and three different forest cover types (eastern larch, productive black spruce, and stagnant black spruce) to understand how vegetation, hydrology, soils, and wildlife species interact within peatland forest communities. Over the course of the 48 years, we have measured thousands of trees and hundreds of different plant species to gain a fuller picture of plant species diversity and growth within peatland forest communities. We have some of the most robust data on boreal chickadee habitat use and early survival, which is critical for this species of great conservation need in Minnesota. Finally, we have hundreds of data points over multiple years on the daily hydrology within these systems to understand how water levels change over the growing season. All of this is critical base line data that can help information management practices within peatland forest communities. Results have been shared locally, regionally, and nationally through presentations and webinars, which include the basic data and sharing how to gather collectively across multiple disciplines to inform holistic management practices within forest ecosystems. Our results show that peatlands are not negatively impacted by harvesting in the vegetation and hydrology. Additional work is needed to consider how different harvest strategies may influence wildlife use within peatland forest ecosystems.

PROJECT RESULTS USE AND DISSEMINATION
We are currently working on final edits and submission for two peer reviewed papers with an additional two papers in progress that will continue outside of the granting program. Results have been shared through multiple forms including local news stories, including Scientists hang 500 birdhouses in Sax-Zim Bog to study boreal chickadees, presentations to forest managers at the Research Review hosted by the Sustainable Forest Education Cooperative, to a special symposium on wet forests which brought together researchers and managers to discuss opportunities and challenges within peatland forest communities.

Project Completed: 6/30/2022

FINAL REPORT

Subd. 03e Assessing Natural Resource Benefits Provided by Lichens and Mosses - Research Project - $213,000 TF

Daniel Stanton
U of MN
1479 Gortner Ave, 140 Gortner Labs
St. Paul, MN 55108

Phone: (651) 494-7625
Email: stan0477@umn.edu

Appropriation Language
$213,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to survey, map, and analyze mosses and lichens across the state, including their moisture-retention capacity, effects on hydrology, and ability to filter airborne pollutants. 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
We documented the potential impact of moss and lichen on the flow of water and pollutants through Minnesota forests. This impact varies across the state depending on the forest type but can reach more than 15% of each rain event. Pollutant filtering effects are smaller but not unimportant.

OVERALL PROJECT OUTCOME AND RESULTS
Moss and lichen are common in forests, and yet they are often overlooked. But this does not mean unimportant: they retain water and heavy metals, and so a mossy forest may function quite differently from a barren one. This project aimed to quantify how much moss and lichen is in Minnesota forests and to estimate their impact on water flows and pollutant retention.

To reflect the diversity of Minnesota's landscape, we established 83 plots in 30 counties across the stateto provide detailed and region-specific coverage of all of the major forest types recognized by the DNR. We recorded which species were present, their abundance (on forest floor, tree trunks and fallen branches), and collected the most abundant ones for lab analyses. 1650 unique specimens were collected.

The amounts vary greatly across the state, from less than one pound per acre to over 1,500 pounds per acre. These translate into sometimes considerable water storage capacity. With respect to heavy metals, contents were often quite low, at fractions of a pound peracre. We will follow up with future work on urban lichens to determine whether this is due to the lack of pollutants in forest sites. By combining our results with existing maps of forest coverage, we've been able to map these contributions across the state.

Another objective of the work aimed to test these estimates with experiments of how much water and elements are retained in the lab and field. Due to delays, these experiments were only installed in Spring 2022, and their continued monitoring and analysis will be funded from other sources.

Overall, our findings draw needed attention to an overlooked component of our forests, both in terms of diversity and impact on water cycles.

PROJECT RESULTS USE AND DISSEMINATION
The activities and findings in this project have been shared with the general public through a number of venues, including public presentations through Minnesota Master Naturalists, Minnesota Mycological Society, and the Bell Museum of Natural History; workshops attended by 30-50 people each at Minnesota Naturalists Association Annual Meeting (2019) and Cedar Creek Ecosystem Reserve (2019, 2022-115 participants!); a booth in the University of Minnesota pavilion at the MN State Fair and several other events. Scientific dissemination has so far included an undergraduate-led peer-reviewed publication and oral presentations at three international conferences. Further scientific publications are planned for late 2022.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 03g Conserving Minnesota's Forest Birds of Management Concern - Research Project - $500,000 TF

Alexis Grinde
U of MN - Duluth NRRI
5013 Miller Trunk Hwy
Duluth, MN 55811

Phone: (320) 496-0016
Email: agrinde@d.umn.edu

Appropriation Language
$500,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Natural Resources Research Institute in Duluth to identify forest-management actions and guidelines to conserve birds in Minnesota's forests. 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
Golden-winged Warbler, Veery, and American Woodcock are species of conservation concern in Minnesota and have had significant population declines throughout their breeding ranges. We documented nest success and used radiotelemetry to study juvenile survival to identify habitat characteristics and management actions that maximize productivity and inform conservation efforts.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesota’s forests provide critical breeding habitat for hundreds of resident and migrating bird species. Current land use practices and future modifications to Minnesota’s forests are likely to substantially transform native forest bird communities. Golden-winged Warbler, Veery, and American Woodcock are species of conservation concern in Minnesota and have had significant population declines throughout their breeding ranges. For breeding birds, conservation efforts are most effective when management plans include recommendations aimed at maximizing breeding season (nesting to post-fledgling) productivity. However, the period of time directly after young birds leave the nest and

before they disperse and/or migrate (i.e., the post-fledging period), remains an understudied life stage for most bird species. To address this knowledge gap, we documented nest success and used radiotelemetry to study juvenile survival and habitat use for Golden-winged Warbler, Veery, and American Woodcock in managed forests. Our results showed that nest success (one or more birds fledged per brood) was 47% for Golden-winged Warblers (n= 51), 39% for Veery (n= 43), and 67% for American Woodcock (n= 13). Documented nest failure for all species was due to predation and weather events. A total of 72 Golden-winged Warbler fledglings were tagged with a survival rate of 39%. Juvenile survival was highest for Veery fledglings (n= 35) at 83%. A total of 31 American Woodcock hatchlings were tagged during the study with a survival rate of 71%. Over 85% of mortality events occurred when birds were less than seven days post-fledge, indicating this as a high-risk time period for these species. Vegetation surveys were completed at all locations where birds were detected using handheld telemetry (Golden-winged Warblers (n= 620), Veery (n= 384), and American Woodcock (n= 281)). These data are being used to provide breeding cycle habitat recommendations for managing forested landscapes to maximize productivity and prioritize conservation efforts.

PROJECT RESULTS USE AND DISSEMINATION
The preliminary results of the research were presented at 13 conferences during the course of project; the study was featured on MPR; and four articles have been written about different aspects of the study. Data from this research was incorporated into a fact sheet "Managing for Birds of Conservation Interest in the Great Lakes Region", which features habitat and management recommendations for Golden-winged Warbler. Three peer-reviewed publications are expected to be published in 2023. The final results will be incorporated into the Golden-winged Warbler habitat management recommendations.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 03h Mapping Avian Movement in Minnesota - Research Project - $200,000 TF

Alexis Grinde
U of MN - Duluth NRRI
5013 Miller Trunk Hwy
Duluth, MN 55811

Phone: (218) 788-2747
Email: agrinde@d.umn.edu
Web: http://www.nrri.umn.edu

Appropriation Language
$200,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Natural Resources Research Institute in Duluth to pilot the establishment of a network of automated radio-telemetry stations to monitor bird migration and local movements and to develop strategic plans for using the infrastructure long term to monitor animal movement for conservation. 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
We used automated radio telemetry to understand habitat needs of Minnesota's birds. Specifically, we tracked birds across large and local-scales to document breeding, migratory and winter movements. Automated radio telemetry systems are useful for studying animal movements and can help to increase public awareness and impact for conservation efforts.

OVERALL PROJECT OUTCOME AND RESULTS
We explored the use of automated radio telemetry for tracking Minnesota's birds. We documented large-scale movements along the north shore of Lake Superior with Blue Jays and Northern Saw-whet Owls, colonial waterbird behavior on Interstate Island with Common Terns, local-scale migratory stopover in the St. Louis River Estuary with Rusty Blackbirds, and winter activity levels and movements in Hartley Park with Black-capped Chickadees. Each of these studies provided us with a greater understanding of the flexibility and adaptability of automated radio telemetry technology to answer a range of questions in different situations and seasons. Overall, we found the use of this technology to document small-scale movements of Rusty Blackbirds, Black-capped Chickadees, and Common Tern to be the most valuable and suggest it as a relatively low-cost way to study local movements while potentially enhancing migration studies simultaneously. For example, using an automated telemetry station at Interstate Island allowed us to obtain additional behavioral information on breeding Common Terns before the birds left and interacted with any foreign automated radio telemetry towers registered on the Motus system. We suggest researchers that are deploying VHF tags for the purposes of long-range migratory studies strongly consider deploying automated telemetry stations like those we developed for this project in strategic locations nearby tagging sites. In this way, researchers will be able to obtain potentially large amounts of local-scale data that can then be used to inform and enhance any large-scale detections after a bird migrates from the trapping site. Bird tracking research has broad public appeal, and stories of bird migrations provide an effective way to engage non-scientists and even non-birders in understanding the many threats small migratory landbirds face.

PROJECT RESULTS USE AND DISSEMINATION
The preliminary results of the research were presented at eight conferences during the course of project and the study was featured on MPR in 2019. Two peer-reviewed publications are expected to be published in 2022, one focusing on Common Tern and other on Rusty Blackbirds. We set up an additional Motus station at Sax-Zim Bog in 2020 to help facilitate research in this important area of the state. We established a website for the citizen science portion of the Black-capped Chickadee study in Hartley Park. A full report for this study is available on the Natural Resources Research Institute website.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03j Develop Sonar Data Mapping on Three Rivers to Assess Suitability for Native Mussel Habitat - Research Project - $200,000 TF

Nancy Duncan
National Park Service
111 E Kellogg Blvd, Ste 105
St. Paul, MN 55101

Phone: (651) 293-8434

Email: nancy_duncan@nps.gov
Web: https://www.nps.gov/miss/index.htm

Appropriation Language
$200,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the National Park Service to create high-resolution sonar data maps to identify critical native mussel habitat for the designated Lower St. Croix National Scenic Riverway and the Mississippi National River and Recreation Area including part of the Minnesota River.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Baseline information in the form of bathymetry and imagery were developed for the National Park Service for native mussel habitat suitability. These data have the analytic capabilities to be viewed and modeled in a digital environment to help understand mussel distribution, define preferred habitat parameters, and identify key habitat locations for restoring imperiled mussels.

OVERALL PROJECT OUTCOME AND RESULTS
The U. S. Geological Survey (USGS) collected depth information and sidescan imagery for areas of the National Park Service (NPS) Mississippi National River and Recreation Area (MISS) and the St. Croix National Scenic Riverway (SACN). For known locations of preferred mussel habitat, additional collection efforts of river flow velocities and underwater video of bed composition were collected. Prior to this project, MISS had no accessible bathymetry data above Pool 1, and SACN did not have any accessible bathymetry (other than a small area near Prescott, Wisconsin). The LCCMR ENRTF provided the opportunity to acquire bathymetry data where needed and make this information available to NPS resource management to help aid decision-making for the conservation of native mussels. Goals for this project were to collect high-resolution sonar data of three rivers where none previously existed. The data is delivered in digital format for modeling hydraulic variables related to native mussel habitat suitability. The USGS provided usable information in the form of bathymetry and topography (hillshades and sidescan imagery) for areas of full collection, and habitat measures of flow velocities and bed characterization for priority areas. Initially implemented as a two-year project, data collection was planned for each park in consecutive years. Due to the pandemic, some data collection was delayed a year. Bathymetric surveys for the lower SACN consisted of approximately 1,775 hectares (4,385 acres), and approximately 1,358 hectares (3,335 acres) were collected for MISS. Outcomes consisted of high-resolution bathymetry in the form of 0.5-meter digital elevation models, 3-D hillshade representations of the surface (using patterns of light and shadow), and sidescan images mosaics — which provide an underwater view of geomorphic features. Flow velocities and bed composition combined with bathymetry can be used to locate areas with similar features as the NPS priority areas. In order to provide complete coverage for MISS, the U.S. Corps of Engineers (USACE) main channel data were used for Pools 1, 2, and 3. The resulting merged bathymetry were generated at a lower resolution (5 meters) due to USACE collection parameters. This project is significant because it provides bathymetry where none previously existed for Minnesotans, and it provides valuable information to the NPS for imperiled mussel habitat modeling by locating other suitable areas for conservation efforts. Natural resource management and policy makers face an increasing number of environmental issues. These data combined with other river conditions can be used to help inform decision-making for aquatic invasive species, agricultural practices, riverfront development, erosion, sedimentation, and climate change.

PROJECT RESULTS USE AND DISSEMINATION
Dissemination included a formal USGS review for data and metadata, prior to release on the USGS data

repository. Datasets and metadata for the St. Croix National Scenic Riverway and the Mississippi National River and Recreational Area can be found online. This project was posted as a resource for current USGS projects at Develop Sonar Data Mapping on Three Rivers to Assess Suitability for Native Mussel Habitat (usgs.gov).

The information resulting from this project is currently being incorporated into a Freshwater Mussel Database (NPS Focused Condition Assessment) for MISS and SACN, which will further be linked to a Freshwater Mussel Decision Support System (USGS Natural Resource Preservation Program) for resource management. Furthermore, the NPS and USGS partnership plan to pursue additional funding for MISS to map untapped information that can be derived from the sonar data; and to collect additional bathymetry and flow data where none still exists on SACN.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 03k Conserving Minnesota's Nine Species of Freshwater Turtles - Research Project - $300,000 TF

Seth Stapleton
Minnesota Zoological Garden
13000 Zoo Blvd
Apple Valley, MN 55124

Phone: (952) 431-9443
Email: seth.stapleton@state.mn.us
Web: www.mnzoo.org

Appropriation Language
$300,000 the second year is from the trust fund to the Minnesota Zoological Garden to improve the long-term viability of Minnesota's imperiled turtle populations by researching threats, identifying mitigation strategies, implementing mechanisms to reduce threats and mortality, and creating related outreach and educational materials. 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 Minnesota Zoo conducted research and implemented conservation actions including nest site protection and head-starting to bolster wood turtle populations. We studied methods to mitigate road mortality of turtles, with results suggesting that simple tube barriers may be effective. Our outreach efforts raised awareness and encouraged action to benefit conservation.

OVERALL PROJECT OUTCOME AND RESULTS
Native turtles are a key component of diverse, healthy, and resilient aquatic ecosystems, inspiring connections to nature for children and adults alike. However, populations of turtles in Minnesota face numerous threats, including habitat loss and degradation, high predation of incubating nests, and mortality on roadways. With this project, the Minnesota Zoo sought to improve the conservation of turtles by 1) collecting data to quantify two key threats – road mortality and nest predation – and

implement and evaluate mechanisms to mitigate these threats; and 2) building public awareness by developing educational and outreach materials for use during on- and off-site programming.

We outfitted imperiled wood turtles with radio and GPS transmitters, improving our understanding of their habitat needs and allowing us to identify and protect nesting sites. We reared hatchling wood turtles in captivity for their first year of life to improve their chances of survival in the wild and bolster depleted populations while other threats are addressed. To date, we have successfully released 68 one-year-old wood turtles back to the wild.

We also investigated strategies to mitigate mortality of turtles on Minnesota's roadways via cost-effective mechanisms including wildlife warning signs and small barriers. Although warning signs did not significantly reduce turtle mortality, corrugated pipe barriers were promising and yielded a decline in mortality of ~50%.

Finally, a variety of materials, including interpretive signage, a 3-dimensional snapping turtle model, and a children's book, were created to support educational and outreach programming and inspire public action to benefit the conservation of turtles. Healthy populations of turtles are an integral component of aquatic systems, and we anticipate that our results will inform effective management strategies that can benefit conservation at sites state-wide.

PROJECT RESULTS USE AND DISSEMINATION
Sharing information about the importance of turtles and their conservation was a key objective of this project. The Minnesota Zoo used a variety of platforms to disseminate significant findings and engage the general public in the conservation of Minnesota's aquatic resources, ranging from informal talks, public lectures and tabling events to media spotlights and distributing content on our social media channels. Media highlights include features on PBS's Prairie Sportsman, Kare 11's Minnesota Bound, a Minnesota Lottery commercial, and a variety of other print and television media outlets. This professionally produced video highlights the ecology and conservation of turtles in Minnesota.

Project Completed: 6/30/2022
FINAL REPORT
Reduce Vehicle-Animal Collisions with Installation of Small Animal Exclusion Fencing - 45 pgs
Poster - Mitigating Road Mortality
Poster - Builing Public Awareness
Poster - Tracking Imperiled Turtles

Subd. 04 Water Resources

Subd. 04a Pilot Program to Optimize Local Mechanical and Pond Wastewater-Treatment Plants - $700,000 TF

Joel Peck
Minnesota Pollution Control Agency
520 Lafayette Rd N
St. Paul, MN 55155

Phone: (651) 757-2202

Email: joel.peck@state.mn.us
Web: https://pca.state.mn.us

Appropriation Language
$89,000 the first year and $611,000 the second year are from the trust fund to the commissioner of the Minnesota Pollution Control Agency, in partnership with the Minnesota Rural Water Association and the University of Minnesota's Technical Assistance Program, to implement a pilot program to optimize existing local mechanical and pond wastewater-treatment systems to increase nutrient removal and improve efficiency without requiring costly upgrades.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Wastewater treatment systems are critical infrastructure to manage waste effluent within hundreds of communities throughout Minnesota. Optimization means getting better results through existing infrastructure. This project determined that both mechanical and pond wastewater treatment systems can be optimized, and new effluent limits met, without adding substantial new infrastructure.

OVERALL PROJECT OUTCOME AND RESULTS
Achieving better nutrient treatment in wastewater treatment facilities serves to reduce the likelihood of algal blooms in Minnesota's water bodies resulting in cleaner lakes and rivers.

This project found that Minnesota's mechanical wastewater treatment plants can achieve better biological nutrient removal (BNR) through low-cost operational changes. These improvements were modeled using the Activated Sludge SIMulation Model (ASIM) in order to determine the specific plant operational parameters required to achieve BNR. On average, mechanical plants in this pilot were modeled to have average nitrogen reduction of 14.14 mg/L, average phosphorus reduction of 1.84 mg/L (most sites already treat phosphorus chemically to 1 mg/L) and chemical reductions of 886 lb chemical/Million Gallons (MGal) flow.

Wastewater ponds can achieve much better nutrient treatment by utilizing the 'Steady-State Primary' strategy developed during this project. This strategy involves holding the first pond at six feet, or the maximum depth permitted) with a slide gate. Raw influent continues flowing into pond 1, while treated effluent from pond 1 is used to fill pond 2. Meanwhile, pond 3 is also held full. This strategy maximizes treatment time and drastically improves nutrient treatment quality. The two developed case studies showcase a 69% reduction in phosphorus and 43% reduction in nitrogen when compared to the prior year's effluent. Secondary recommendations to wastewater ponds is to reduce inflow and infiltration, reduce fecal loading from waterfowl, and to encourage the growth of aquatic plants, with a specific emphasis on the growth of coontail.

By quantifying the role that optimization has in effective wastewater treatment, Minnesota's lakes and streams can meet standards in a more cost effective means.

PROJECT RESULTS USE AND DISSEMINATION
The project and its results have been presented in 17 different events and conferences by members of this team, including Minnesota Rural Water Association's annual conference, Minnesota Pollution Control Agency's annual conference, the Conference on the Environment, and many others. However, only one mechanical treatment plant has elected to move ahead with a pilot study, and one additional has expressed interest in doing so in the near future. The team has heard from staff and consultants of

participating facilities that without a nitrogen standard as a driver, they feel little urgency to adopt optimization recommendations. Other facilities are meeting phosphorous limits under current flow, but would face difficulty at increased flow. Additionally, BNR design and operation is not a common treatment system in our Minnesota climate, and there may be some trepidation to moving toward that form of treatment until other facilities lead the way.

We have seen eight pond systems adopt the steady-state-primary flow regime in their operations, with more hoping to do so in the near future. Those that have done so already have reported roughly 50 percent reduction in nutrient discharge. The flow regime still needs additional validation. But, more discharge events will add more confidence with additional datasets from daily monitoring reports. Better flow management through infrastructure maintenance – making sure the control structures function as designed – is going to continue to be an area of importance in order to prevent short circuiting of the treatment in isolated pond cells.

The final report, the final work product of operator field guides for mechanical and pond treatment facilities, case studies of participating facilities, and additional findings, can all be found here, at the Minnesota Technical Assistance Program's wastewater webpages.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 04b Assess and Develop Strategies to Remove Microscopic Plastic-Particle Pollution from Minnesota Water - $300,000 TF

Filippo Coletti
U of MN
110 Union St SE
Minneapolis, MN 55455

Phone: (650) 289-8216
Email: fcoletti@umn.edu

Appropriation Language
$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to assess, track, and develop methods to remove microscopic plastic particles that are dispersed and accumulating as pollution in Minnesota water bodies. This appropriation is subject to Minnesota Statutes, section 116P.10. 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
We performed a comprehensive study on the motions of microscopic plastic particles in water flows. Extensive experiments have been conducted utilizing innovative imaging techniques on laboratory apparatuses, assisted by state-of-the-art simulations on supercomputers. Valuable data have been collected and analyzed for addressing the plastic pollution in Minnesota water bodies.

OVERALL PROJECT OUTCOME AND RESULTS
The amount of plastic waste in lakes and rivers is projected to increase, driven by the rise in plastics

consumption. New federal and state legislation has banned the sale of certain products containing micro-beads, but thousands of tons of micro-plastic pollution are already in our waters and will take thousands of years to biodegrade. The objective of this project is to utilize the advanced facilities at the St. Anthony Falls Laboratory to carry out a series of experiments and use powerful computation simulations to investigate the motions of microplastics.

This project carried out extensive laboratory measurements of the motion of spherical and non-spherical particles (fibers and disks) in water channel flows. We also conducted the first-ever field measurements of particles transported on the water surface of a small river facility in the Outdoor StreamLab at the St. Anthony Falls Laboratory. Extensive analyses have been performed on the measurement data. We discovered that fibers tend to orient mostly in the streamwise direction while disks maintain their symmetry axis quasi-normal to the water bottom. The fibers undergo strong tumbling near the bottom in response to the mean shear and turbulent fluid velocity fluctuations, whereas the disks wobble about their preferential bottom-normal orientation. We also developed an advanced computer simulation method for the motions of plastic particles in water flows that can capture particle-particle interactions and particle-flow interactions with unprecedented realism and accuracy. We conducted numerical experiments using a supercomputer to study the effect of breaking waves on the surfaces of lakes and rivers on the transport of microplastics. Using computer simulation, we have also revealed the relationship between microplastic's preferential orientation in water waves and particle shapes. We have also elucidated the microplastics transport process through comparing the motions of spherical particles, oblate particles. and a mixture of both particles to quantify their transport characteristics in water bodies.

PROJECT RESULTS USE AND DISSEMINATION
In this project, substantial efforts have been put into sharing the knowledge gained from the research through presentations at national conferences, such as the annual meetings of the American Physical Society, Division of Fluid Dynamics and the Fall Meetings of the American Geophysical Union. A paper has been published in the Journal of Fluid Mechanics ("Experimental investigation of inertial fibres and disks in a turbulent boundary layer" by Lucia Baker and Filippo Coletti, vol. 943, A27), which is a leading journal in the field.

Project Completed: 6/30/2022
FINAL REPORT
Experimental investigation of inertial fibres and disks in a turbulent boundary layer

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Subd. 04c Reduce Chlorides in Minnesota Waters by Evaluating Road-Salt Alternatives and Pavement Innovations - $400,000 TF

John Gulliver
U of MN
2 Third Ave SE
Minneapolis, MN 55414

Phone: (612) 625-4080
Email: gulli003@umn.edu

Appropriation Language
$400,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to investigate road-salt alternatives and pavement innovations to reduce lake, stream, and groundwater degradation caused by road-salt chlorides. 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 produced background information, guidance and recommendations on the benefits and consequences of chloride-based road salt and non-chloride alternatives for de-icing and anti-icing Minnesota's roadways, which will assist road maintenance decision makers in reducing pollution from winter road management.

OVERALL PROJECT OUTCOME AND RESULTS
Over 100,000 tons of road salt are applied to Minnesota's roads each year to prevent or reduce snow and ice cover during the winter season. Sodium chloride is typically used because it is inexpensive and effective, but it can corrode vehicles, pavement, and metal structures (e.g., bridges), and it increases chloride concentration in surface and ground waters throughout the state. This results in additional costs for replacing roadway infrastructure and reduces water quality, habitat, and biodiversity in our natural resources. This project investigated alternatives to sodium chloride-based road salt that reduce snow and ice on roadways with less environmental impact. The project team reviewed scientific research papers, performed laboratory experiments, and used computer models to predict the potential environmental impacts of these chemicals on Minnesota's natural resources.

This project found several outcomes, including: 1) chloride-based road salt concentration can exceed the chronic and acute water quality standards during a typical year; 2) acetate-based alternatives only exceeded water quality standards for low flow rates (low dilution); 3) potassium-based chemicals can be toxic at low concentration, and toxicity thresholds are exceeded when potassium is applied over all roadways for all winter storms; 4) other alternatives such as formate, glycol, glycerol, and succinate have varying performance, application rate, and toxicity thresholds; 5) water-heated sand improves friction compared to bare ice or dry sand on bare ice and can be removed from the environment with simple grit collection chambers; and 6) non-chloride alternatives can reduce the bonding strength of ice to a solid surface. Thus, water-heated sand as an abrasive and organic or hydrophobic non-chloride alternatives can be used to reduce the use of chloride-based road salt and provide more winter benefit on Minnesota's roadways, but modeling predicts that some of these chemicals could exceed toxicity thresholds if applied for all conditions.

PROJECT RESULTS USE AND DISSEMINATION
The results from this project have been shared via presentations, interviews, reports, academic journals, and with stakeholders and decision makers during conferences and networking events. Some examples include a web article, two invited annual Minnesota Salt Symposium presentations (2019 & 2021), WCCO's 10 o'clock news "Good Question: How Does Salt Melt Ice?" with Jeff Wagner, the Transportation Research Board Annual meeting (2022), and several conference presentations and professional meetings. We believe sharing this information has enlightened decisions makers about the dangers of chloride road salts and non-chloride alternatives and how best to use each.

Project Completed: 6/30/2022
FINAL REPORT
Road Salt Alternatives and Pavement Innovations

Subd. 04d Protect Water Quality with Efficient Removal of Contaminants in Treatment Ponds for Storm Water - $325,000 TF

Heiko Schoenfuss
St. Cloud State University
720 Fourth Ave S WSB-273
St. Cloud, MN 56301

Phone: (320) 308-3130
Email: hschoenfuss@stcloudstate.edu
Web: http://web.stcloudstate.edu/aquatictox/

Appropriation Language
$325,000 the second year is from the trust fund to the Board of Trustees of the Minnesota State Colleges and Universities system for St. Cloud State University to evaluate the effectiveness of best management practices in removing contaminants from storm water to safeguard aquatic 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
Our study demonstrates that pharmaceuticals and pesticides are commonly found in urban stormwater and can impact aquatic life. Stormwater ponds, especially when augmented with iron-enhanced sand filtration, can often reduce these pollutants, and lessen their impact on Minnesota aquatic environments.

OVERALL PROJECT OUTCOME AND RESULTS
Urban stormwaters carry pollutants, including pharmaceuticals and pesticides, into Minnesota streams, rivers, and lakes. Stormwater ponds have not been studied to determine whether they are effective in removing these pollutants. The goal of this study was, therefore, to assess stormwater composition and treatment to inform natural resource managers to the best options for reducing urban stormwater related pollution to Minnesota waters. Our approach combined water chemistry analysis and assessment of biological toxicity in a range of species living in Minnesota waters. We sampled inflow and outflow of seven urban stormwater ponds across seasons and included traditional ponds and those augmented with additional iron-enhanced sand filters. Each water sample was analyzed for a range of pollutants and was also used to expose cells of animals living in Minnesota waters to assess the samples' toxic potential. Pharmaceuticals and pesticides were commonly found in stormwater. In nearly three-quarters of paired water samples (pond inflow and pond outflow), pharmaceutical concentrations were reduced in the outflow when compared to the inflow. Similarly, in about half of paired samples, pesticide concentrations were lower in the outflow sample. The measured reduction in pollutants was also reflected in improved cell health, but this effect was neither as pronounced nor as widespread as predicted by the water chemistry results. In some instances, exposed cells from some, but not all species did better in inflow water than outflow water and in some instances no changes in cell health were observed. The inconsistency in observed biological improvement may be the result of seasonal differences and/or conditions in specific stormwater ponds. This study demonstrates for the first time

that stormwater ponds are effective treatment options to reduce the impact of pharmaceuticals and pesticides on urban aquatic environments. Adding additional filtration, such as iron-enhanced sand filtration can further reduce stormwater pollutants.

PROJECT RESULTS USE AND DISSEMINATION
Despite the challenges associated with the Covid-19 pandemic, our team was able to give seven presentations related to this study. These include presentations to natural resource managers in Minnesota and to toxicologists at national and international scientific meetings. A St. Cloud State University graduate student completed a thesis on this project in 2020 which is currently being developed into a manuscript. Water chemistry data were integrated into a national USGS data base. Additional manuscripts are being prepared for future publication.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 04e Develop Small and Inexpensive Purification System for Community Drinking Water - $425,000 TF

Tianhong Cui
U of MN
111 Church St SE
Minneapolis, MN 55455

Phone: (612) 626-1636
Email: tcui@me.umn.edu

Appropriation Language
$425,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a small and inexpensive purification-technology system for community drinking-water facilities to remove toxic contaminants, make water safe to drink, and improve drinking-water quality. This appropriation is subject to Minnesota Statutes, section 116P.10. 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 designed a small water purification system for drinking water that can simultaneously remove the organic pollutants and heavy metal ions in the water. The system can be connected either to domestic drinking water taps or to water in lakes and rivers.

OVERALL PROJECT OUTCOME AND RESULTS
This project is dedicated to providing clean drinking water to the Minnesota community by designing and manufacturing a small water purification system and providing a possible solution for the water treatment of large water plants. A compact size prototype was first designed to verify the mechanism. Photocatalysis technology was used to remove the organic pollutants, and titanium dioxide was selected as the photocatalyst. Electrochemical reduction was applied to remove heavy metal ions in the water. Finally, the team innovatively combined photocatalysis and electrochemistry to develop a photoelectrocatalytic solution that can simultaneously remove organic matter and heavy metal ions from water. The result shows that the compact system can remove 91.6% percent of the 10-micrometer

methylene blue when the mass flow rate is 14.4 milliliters per hour (mL/h), and around 97.5% of 200 parts per million of copper(II) cations (Cu2+) can be removed at the same time. After the theory of photoelectrocatalysis was verified, standard-sized systems were designed and fabricated comprising an ultraviolet lamp, a chamber with active carbon, and a microfluidic system with immobilized photocatalyst. The standard-size system can remove nearly 100% of the 10-micrometer methylene blue and 96% of the Cu2+ in the water with a flow rate of 50 mL/h. The team conducted the field test with the drinking water from Commonwealth Terrace Cooperative, a community for University of Minnesota students and their families, and the water from Mississippi River. The testing results demonstrate the capability of using the designed system to remove organic pollutants and heavy metal ions in the water.

PROJECT RESULTS USE AND DISSEMINATION
On-site demonstration and tests as described in the activities at a student housing community and Mississippi river from May through June 2022. Communications with interested entrepreneurs have been ongoing with interested parties including local companies and individuals.

The following papers published in archived journals and prestigious conferences:

1. Zhou, P., & Cui, T. (2020). Enhanced photocatalytic efficiency by layer-by-layer self-assembly of graphene and titanium dioxide on shrink thermoplastic film. Microsystem Technologies, 26(12), 3793-3798.
2. Zhou, P., Zhang, T., Simon, T. W., & Cui, T. (2021). Simulation and Experiments on a Valveless Micropump With Fluidic Diodes Based on Topology Optimization. Journal of Microelectromechanical Systems, 31(2), 292-297.
3. Zhang, T., Zhou, P., Simon, T., & Cui, T. (2022). Vibrating an air bubble to enhance mass transfer for an ultra-sensitive electrochemical sensor. Sensors and Actuators B: Chemical, 354, 131218.

Professor Tianhong Cui presented five invited public seminars and talks on water sensors:
Invited Talk, University of Bath, July 4, 2022
Invited Talk, University of Cambridge, July 11, 2022
Invited Talk, EcoLab, May 4, 2022
Invited Talk, French-American Innovation Days, Water Management in Cities, April 8, 2021 (on-line)
Invited Talk, University of Texas at San Antonio, September 13, 2019

Project Completed: 6/30/2022
FINAL REPORT
Enhanced photocatalytic efficiency by layer-by- layer self-assembly of graphene and titanium dioxide on shrink thermoplastic film
Simulation and Experiments on a Valveless Micropump With Fluidic Diodes Based on Topology Optimization
Vibrating an air bubble to enhance mass transfer for an ultra-sensitive electrochemical sensor

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Subd. 04f Evaluate Emerging Pathogens in Lakes, Rivers, and Tap Water to Keep Drinking Water Safe - Research Project - $325,000 TF

Timothy LaPara
U of MN

500 Pillsbury Dr SE
Minneapolis, MN 55455

Phone: (612) 624-6028
Email: lapar001@umn.edu
Web: http://web.stcloudstate.edu/aquatictox/

Appropriation Language
$325,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to evaluate emerging pathogens including Legionella and mycobacteria to ensure that surface water used for drinking water and tap water is safe to drink. 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
Seven full-scale drinking water systems were investigated for the presence of Legionella and Mycobacteria, opportunistic bacterial pathogens of health concern. This research demonstrates these organisms are commonly found in drinking water during the late summer/early fall; water utilities are encouraged to sustain a residual disinfectant to help suppress these pathogens.

OVERALL PROJECT OUTCOME AND RESULTS
The goal of this project was to investigate the presence of opportunistic pathogens at seven public water utilities within the State of Minnesota that treat surface water (i.e., lakes and rivers), as those water sources are expected to be at greater risk of pathogen contamination than deep groundwater wells. Samples were collected from the water prior to treatment (i.e., the water supply), the water immediately after treatment (i.e., finished water), and at two locations from within each drinking water distribution system. Each of the seven utilities was sampled from one to five times at the four locations for a total of 94 unique sample events.

This project demonstrated that known opportunistic pathogens (e.g., Legionella species) can be routinely detected throughout the year in surface water supplies in Minnesota and that water treatment is effective at removing them by 99% or more in most cases. The most concerning opportunistic pathogens that we tested for, Legionella pneumophila and Mycobacterium avium complex (MAC), were rarely detected and all the observed concentrations in tap water were well below the levels whereby these organisms would be of direct concern (i.e., none of our research results suggest a direct concern with respect to human health). Our results, however, are of indirect concern because these organisms could multiply within a drinking water distribution system should the conditions become favorable for their growth. Hence, our recommendation is that water utilities meticulously maintain a residual disinfectant throughout their distribution systems, particularly in the late summer/early fall when the warmer water creates conditions where Legionella species and MAC are most likely to multiply in the system and to be detected.

PROJECT RESULTS USE AND DISSEMINATION
Dissemination activities related to this project were severely hindered by the COVID-19 pandemic. We were, however, able to make two different presentations of our preliminary results to the Minnesota Section of the American Water Works association; these presentations were titled “Emerging Pathogens in Lakes, Rivers, and Tap Water” (September 24, 2020) and “Opportunistic Pathogens in Lakes, Rivers, and Tap Water” (September 16, 2021). We are currently writing three different manuscripts for

publication in the peer-reviewed literature that will include the results from this study. We will also share our results with Minnesota Department of Health personnel.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 04g Characterize Unregulated Contaminants in Source Water and Drinking Water - $1,000,000 TF

Stephen Robertson
Minnesota Department of Health
625 Robert St N
St. Paul, MN 55164

Phone: (651) 201-4648
Email: steve.robertson@state.mn.us
Web: http://www.health.state.mn.us/

Appropriation Language
$1,000,000 the second year is from the trust fund to the commissioner of health to establish monitoring networks of public water-system wells and surface-water intakes to determine if contaminants persist after standard public water treatment. 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
Analysis of drinking water resources reveals the presence of a range of unregulated contaminants at low levels. Most of these levels are below health-based guidance, if available. Results are being used to inform development of new health-based guidance and to perpetuate drinking water ambient monitoring.

OVERALL PROJECT OUTCOME AND RESULTS
This project sampled water from 105 public water systems statewide for a wide spectrum of drinking water contaminants. Participating public water systems were organized into three groups: systems that use surface water, systems that use groundwater potentially influenced by wastewater, and systems that use groundwater potentially affected by agricultural land uses. Depending on the group, samples were analyzed for as many as 600 different contaminants, including pharmaceuticals, per- and polyfluoroalkyl substances (PFAS), organic wastewater indicators, and pesticides.

Results for individual systems showed that most contaminants analyzed were not detected in drinking water, but some contaminants were present at low levels. The detections included 84 pesticides, 51 pharmaceuticals, 43 wastewater indicators, 15 PFAS, eight benzotriazoles, and one inorganic compound. Some contaminants were detected at multiple systems. Results were compared against health-based guidance values, if available, although most contaminants analyzed lack health-based guidance values. A few results exceeded available guidance values. In those instances, Minnesota Department of Health staff coordinated with the public water system to validate results and take action where appropriate.

There were detections of contaminants from most classes analyzed, but pesticides and PFAS were the most commonly detected. The most frequently detected contaminants across the study included lithium, pesticides (metolachlor, atrazine, deethylatrazine), PFAS (PFBA, PFHxS, PFOS, PFOA), and tribromomethane. Differences in occurrence or concentration were observed in source versus finished water samples for some groups (e.g., pharmaceuticals, benzotriazoles) but not for others (e.g., PFAS, pesticides). Samples collected in geologically vulnerable settings generally showed higher contaminant concentrations than those collected from non-vulnerable sites.

Results have been used to prioritize and nominate contaminants for the development of health-based guidance. Also, the project has led to creation of a permanent drinking water ambient monitoring program. This ongoing work will help mitigate and manage the exposure to unregulated contaminants through Minnesota's drinking water.

PROJECT RESULTS USE AND DISSEMINATION
The project and associated materials are described on the MDH website. This project has spurred creation of risk communication resources for public water systems and MDH staff.

A project summary report has been prepared and will be available on the MDH website by October 2022.

Preliminary results from the project have been presented at the University of Minnesota's Water Resource Conference (October 2020). A complete analysis of the results is forthcoming and will be prepared for publication.

A professional paper describing the ELISA methodology used in this project is in press for publication. (Krall, Aliesha L., et al, 2022)

Project Completed: 6/30/2022
FINAL REPORT
Comparison of the Results of Enzyme-Linked Immunosorbent Assay (ELISA) to Mass-Spectrometry Based Analytical Methods for Six Unregulated Contaminants in Source Water and Finished Drinking-Water Samples
MN Department of Health - Monitoring Plan - Unregulated Contaminants Monitoring Project

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Subd. 04h Mapping Antibiotic Resistance in Minnesota to Help Protect Environmental, Animal, and Human Health - Research Project - $750,000 TF

Randall Singer
U of MN
1971 Commonwealth Ave
St. Paul, MN 55108

Phone: (612) 625-6271
Email: rsinger@umn.edu

Appropriation Language
$750,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota

to quantify and map antibiotic and antibiotic-resistance gene contamination in Minnesota waters and soils to identify locations in need of mitigation to protect environmental, animal, and human health. 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

Our project mapped and quantified antibiotics and antibiotic resistance genes in Minnesota waters and soils. These findings are now used to target hotspots to better understand their fate and transformation in waterbodies. Ultimately, this information will be used for antimicrobial resistance mitigation strategies to protect environmental, human, and animal health.

OVERALL PROJECT OUTCOME AND RESULTS

Antimicrobial resistance (AMR) threatens human, animal, and ecosystem health. Antibiotic use in hospitals, long-term care facilities, and animal husbandry operations (point sources) play a major role in AMR emergence. Discharges and runoff from these point sources which may include AMR and antibiotics enter the natural environment, especially waterbodies, in some cases after going through a treatment system at the point source itself or at a wastewater treatment plant. The project goals included a) developing an "antibiotic footprint" map of Minnesota's natural environment that would predict areas where antibiotics, resistant bacteria, and antimicrobial resistance genes (ARG) are most likely to accumulate; b) quantifying concentrations of antibiotics and ARG at sites variably impacted by anthropogenic activities; and c) validating the prediction maps with the data collected across the state to develop a risk-based surveillance system that will aid in statewide AMR mitigation efforts in the natural environment. To achieve the overall project goals, an iterative holistic approach was used which included sampling different environmental matrices at different spatial scales, and the use of diverse statistical and spatial methods to map and predict both antibiotics and ARG. The highest antibiotic concentrations were found near human populated areas, while ARG did not present any specific spatial pattern. The macrospatial approach identified hotspot areas of ARG and antibiotic contamination, and the microspatial approach revealed an influence of wastewater on ARG abundance. The maps and predictions created for waterbodies were useful to identify antimicrobial AMR and antibiotic hotspots areas throughout the state, while the maps created for soil can be used for targeted field surveillance of antibiotics. The environment plays a key role in the dissemination and persistence of AMR, which affects human, animal, and environmental health; therefore, these findings are critical to continue developing mitigation strategies of AMR spread in Minnesota.

PROJECT RESULTS USE AND DISSEMINATION

This project has produced two peer-reviewed publications (Bueno, I., et al., 2021; and Bueno, I., et al., 2022), and there will be two others submitted soon summarizing the data for the 2020-2021 field seasons. This project has been presented at nine international and domestic conferences both as poster and oral presentations, and during at least two teaching courses. Also, a graduate student used data from this project to conduct her Master's. One of the dissemination goals was to engage the general public at the state fair, but the COVID-19 pandemic halted that.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 04i Farmer-Led Expansion of Alfalfa Production to Increase Water Protection - $500,000 TF

Nicholas Jordan
U of MN
1991 Upper Buford Cir, 411 Borlaug Hall
St. Paul, MN 55108

Phone: (612) 625-3754
Email: jorda020@umn.edu

Appropriation Language
$500,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a farmer-led, market-based working-lands approach to increase water protection in agricultural areas by targeted expansion of alfalfa production and development of methods to convert alfalfa to high-value bioproducts. 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
Farmers working together in watersheds can build the base of supply chains for new crops that provide continuous living cover of farmland, thereby providing healthy soil, clean water, and abundant wildlife. These supply chains will meet demand for sustainably produced commodities, providing a market-driven pathway to clean water.

OVERALL PROJECT OUTCOME AND RESULTS
We advanced a novel prevention-based strategy for protecting water resources, based on market-driven integration of alfalfa—and other perennial and annual crops that provide continuous living cover (CLC) of farmland—into corn/soybean-based farming operations. Integration of CLC crops will protect water resources, improve soil health, support wildlife, and enhance agricultural production and profit. Specifically, we 1) tested a farmer-led working lands approach for using alfalfa and other CLC crops to improve agricultural effects on water, and 2) did R&D to open new markets for alfalfa. Under 1), we worked with farmers in the Rogers Creek watershed near St. Peter, MN to develop and implement a watershed-scale protection plan based on adoption of alfalfa and other CLC crops, including on-farm implementation plans, and supported pilot-scale production of several novel CLC crops. We monitored water quality, showing that current farming systems are releasing relatively high levels of nutrients. Simulation modeling showed that increased production of alfalfa and other CLC crops can efficiently produce significant improvements in water quality. Economic analyses showed that integrating alfalfa and other CLC crops had good potential to support profitable production. Under 2), we assessed advanced processing and storage practices to reduce moisture-related spoilage and nutrient leaching of alfalfa, identifying eviable practices that reduce these historical impediments to profitable alfalfa production; we developed and assessed new applications for alfalfa, which revealed multiple promising options: biochemicals, nutraceuticals, and high-value sustainably-produced animal and aquaculture feeds; and developed supply-chain connections and identified market opportunities, via development of pilot projects, outreach and knowledge sharing, and novel collaborations. Overall, the project illuminated methods for building new production systems and supply chains needed to support increased production of alfalfa and other CLC crops as a scalable, non-regulatory approach for improving agricultural effects on water resources.

PROJECT RESULTS USE AND DISSEMINATION
We have disseminated results in reports, provided as appendices to the final project report (available in

the Research Reports section here), and many presentations as detailed in the project's reports. These include the 2019 Minnesota River Congress meeting on "Profitable Farming in Time of Climate Change" meeting, a February 2020 industry meeting on alfalfa utilization, a February 2021 exhibition on value-added alfalfa applications at the Midwest Forage Association's Symposium, a July 2021 field day at a Kernza® field attended by 75 industry stakeholders, and a June 2022 "Fields of Opportunity" webinar in June that presented an overview of project findings to a large internet audience.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 04j Using Perennial Grain Crops in Wellhead Protection Areas to Protect Groundwater - $250,000 TF

Margaret Wagner
Minnesota Department of Agriculture
625 Robert St N
St. Paul, MN 55155

Phone: (651) 201-6014
Email: margaret.wagner@state.mn.us
Web: https://www.mda.state.mn.us

Appropriation Language
$250,000 the second year is from the trust fund to the commissioner of agriculture to establish demonstration plots of Kernza, a new intermediate perennial grain crop, to evaluate the potential to profitably reduce nitrate contamination of groundwater in vulnerable wellhead protection regions of Minnesota. Any income generated as part of this appropriation may be used to expand the project.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This study established demonstration fields of Intermediate wheatgrass (Kernza®) within wellhead protection areas in central and southeast Minnesota and research results showed the nitrate reduction potential of targeted placement of perennials in areas with vulnerable groundwater.

OVERALL PROJECT OUTCOME AND RESULTS
Nitrate-nitrogen is one of the most common pollutants in Minnesota's groundwater. In some areas of the state, public and private wells have elevated nitrate levels. Groundwater is most vulnerable to nitrate contamination in central and southeast Minnesota. Areas in central are vulnerable because of widespread sandy soil and in southeast because of shallow bedrock, sinkholes and other geologic features. Intermediate wheatgrass (IWG) is a perennial grass that produces a novel grain, Kernza® and has the potential to reduce nitrate leaching compared to common annual row crop production. This study 1) established demonstration fields of IWG within wellhead protection areas in central and southeast Minnesota and 2) conducted an experiment that compared grain yields, biomass yields, soil nitrate, soil water content, and root biomass under IWG and a corn-soybean rotation for three years on a sandy soil in Central Minnesota. We also 3) conducted grain testing to determine optimum processing of Kernza for various end-use products (crackers, bread, beer, etc). Outcomes included targeted planting of 68 acres of IWG in wellhead protection areas near Chatfield and Verdi. A field day was held at both

sites, engaging over 60 people. Results from Activity 2 found that the mean soil nitrate was 77 to 96% lower under IWG than an annual rotation of corn and soybean. Total soil water content did not differ among cropping treatments. Root biomass was 82% lower under soybean than under IWG. Results from Activity 3 include the development of multiple Kernza cleaning and dehulling process workflows that include equipment needs, costs, and Kernza grain quality outcomes. The results from this project show that IWG effectively reduces the risk of nitrate leaching when grown on wellhead protection areas, and that the farming and food community is eager to continue exploring IWG as a new crop for water protection.

PROJECT RESULTS USE AND DISSEMINATION
Field days at two locations with ~60 participants on site. Events highlighted in newspaper articles. Case study/ project summaries written by Green Lands Blue Waters. Master's student research is in process of being submitted for publication in a peer-reviewed journal. Deliverable for Activity 3 includes a technical report on cleaning intermediate wheatgrass (Kernza) as well as resources for food processors to integrate it into their business operations.

The research supported by this grant is part of a larger network of research and implementation efforts around Kernza. Resources are compiled on a Kernza website, including resources for the cleaning and dehulling process.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 04k Implement a Pilot Credit-Trading System for Storm Water in Shell Rock River Watershed to Improve Water Quality - $300,000 TF

Courtney Phillips
Shell Rock River Watershed District
214 West Main St
Albert Lea, MN 56007

Phone: (507) 379-8782
Email: Courtney.Phillips@co.freeborn.mn.us
Web: http://www.shellrock.org

Appropriation Language
$300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Shell Rock River Watershed District to develop and implement a pilot water-quality credit-trading program for storm water that provides voluntary and cost-effective options to reduce pollution on a watershed scale.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This pilot project developed a water management framework plan along with associated appendices to submit an overlay permit for water quality credit trading to the Minnesota Pollution Control Agency. This work may provide water quality solutions to MS4 permittees bound by funding constraints.

OVERALL PROJECT OUTCOME AND RESULTS
This project was a collaborative effort between the SRRWD, the City of Albert Lea and utilized a technical advisory committee that consisted of Minnesota Pollution Control Agency (MPCA), Board of Water and Soil Resources, and Department of Agriculture staff.

Stormwater credit trading begins when an upstream landowner, or discharger, reduces pollution or nutrients below levels that are required by law. Those nutrient reductions are then verified, and measured by third party scientists and translated into "credits" that are sold to a credit bank. Downstream towns or cities could then purchase those credits instead of spending multi-million dollars in stormwater system retrofits.

The outcome of this project is the Fountain Lake Phosphorus Stormwater Water Quality Trading Management Plan. This document includes the regulatory requirements, policies, trade ratio, credit transaction value, and program administration behind stormwater credit trading. Attached to this plan are the appendices that support the management plans reasoning and forms that could be used to establish a credit trading program. The end result is a set of documents that are ready for an MS4 entity to submit to MPCA for possible approval of stormwater credit trading to take place. Please note the MPCA would have the authority to approve, modify or deny a stormwater credit trading program in the State of Minnesota. A working credit trading program such as this can provide water quality benefits at a reduced cost, contributing to the fishable, swimmable, drinkable waters initiative.

PROJECT RESULTS USE AND DISSEMINATION
Documents that are available for dissemination include the Fountain Lake Phosphorus Stormwater Water Quality Trading Management Plan and the cost effectiveness for water quality trading report. These documents will be sent to the Minnesota Pollution Control Agency, the Board of Water and Soil Resources, and Department of Agriculture. Both documents can also be found on the Shell Rock River Watersheds District website and submitted to LCCMR staff.

Project Completed: 6/30/2021
FINAL REPORT
Fountain Lake Stormwater Water Quality Trading Management Plan, including template forms and letters

Subd. 05 Technical Assistance, Outreach, and Environmental Education

Subd. 05b YES! Students Take on Minnesota Water-Quality Challenge - $213,000 TF

Shelli-Kae Foster
Prairie Woods Environmental Learning Center
12718 10th Street NE
Spicer, MN 56288

Phone: (320) 441-9254
Email: Shelli-kae.Foster@co.kandiyohi.mn.us
Web: www.youthenergysummit.org

Appropriation Language
$213,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Prairie Woods Environmental Learning Center to expand the Youth Energy Summit (YES!) model to improve local waterways by training and mobilizing over 20 youth-led teams in Minnesota communities to complete 30 or more projects related to water quality including monitoring and reporting.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Our project, YES! Students Take on Water Quality Challenge, brought water quality and conservation knowledge and expertise to over 800 students from 126 communities across Minnesota. In 3 years, 81 hands-on water quality and prairie/habitat restoration projects were completed, and 20 waterbodies were improved while engaging with 30 resource experts.

OVERALL PROJECT OUTCOME AND RESULTS
Our project goal was to engage Minnesota's youth in taking on the challenge to improve our state's water ways. We accomplished this goal by:

- Supporting 54 youth-led YES! teams, with over 800 students, in 126 Minnesota communities
- Completing 81 new student-driven water quality and prairie/habitat restoration projects
- Providing 3 Fall Summit events and 27 regional workshops
- Leveraging the expertise and kindness of 6,564 volunteer hours including 3,125 hours of YES! student volunteer hours and $75,000 in community funds
- Awarding the Water Quality Stewardship award in 2019 and 2020

Our aim was to help students to better understand the interconnectedness of their daily actions and water quality. We accomplished this through leveraging the expertise of 30 water quality experts who educated and trained our students about local water quality challenges, techniques to improve and conserve water quality and then assisted them in doing related student-driven projects.

YES! student-driven projects benefited Minnesota communities by improving waterways, cleaning up shorelines, restoring native prairies and establishing new native plantings and habitats. Other projects included Aquatic Invasive Species (AIS) monitoring, assessing drinking water, installing hydration stations, storm drain stenciling (Adopt-a-Drain), water usage tracking and water-related events and peer education.

As one YES! student from Minnewaska said, "I enjoy YES! because of the positive interactions-people taking time out of their day to teach you things. It's something for yourself and it's something to do for your community." Another student from Carlton stated, "It feels really rewarding to know that we are actually making a difference!" Resource expert Phil Votruba commented, "You guys serve as an inspiration for youth across the state and across the country!"

A Sleepy Eye Student remarked "As a part of YES! team I got to participate in River Watch which consists of monitoring Minnesota's rivers and helping to keep them safe. I was able to learn more about what makes the rivers healthy or unhealthy and was able to help in the monitoring process."

PROJECT RESULTS USE AND DISSEMINATION
During this project (July 1, 2018, to June 30, 2021) YES! staff have tabled or presented at 20 events. YES! was featured in 22 outside articles, radio broadcasts and videos. They are listed on our website and can

be accessed here at YES! in the News. In addition, staff posted 86 blog posts to our YES! website which were shared on our social media pages including Facebook, YouTube, and LinkedIn.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 05d Connecting Students with Water Stewardship through Hands-on Learning - $400,000 TF

John Lenczewski
Minnesota Trout Unlimited
PO Box 845
Chanhassen, MN 55317

Phone: (612) 670-1629
Email: jlenczewski@comcast.net
Web: http://www.mntu.org

Appropriation Language
$400,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Minnesota Trout Unlimited to engage students in classroom and outdoor hands-on learning focused on water quality, groundwater, aquatic life, and watershed stewardship and providing youth and their families with fishing experiences. 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 connected approximately 10,000 Minnesota youth with their local watersheds. Through a combination of habitat site explorations, field studies, classroom learning, and outdoor recreation, students gained an appreciation for the natural world and understanding of how their decisions can positively impact water quality and watershed health.

OVERALL PROJECT OUTCOME AND RESULTS
In today's technology-based society, youth are increasingly becoming disconnected from the natural environment. This disconnect can foster apathy about the environment, natural resources, and outdoor recreation, and impact their ability to make well informed decisions about the environment as adults. The program countered this by using tangible education tools and getting students outdoors for hands-on learning activities that connected them to aquatic ecosystems. It utilized classroom aquariums where students studied the development of trout from egg to juvenile. This served as a springboard for field trips to streams and as a focal point for reinforcing learning about water, watersheds, and ecology. Introductions to outdoor recreation were offered to encourage lifelong, tangible connections to aquatic ecosystems.

The number of schools and nature centers participating in this outdoor education program doubled from 29 during the 2018-2019 school year to 60 during the 2021-2022 school year. The program expanded from Twin Cities metropolitan area to schools in Duluth, Bemidji, Alexandria, Willmar, Winona, and other outstate communities. Despite the serious challenges that the COVID-19 pandemic

created for conducting in-person field day and classroom learning, our education team conducted more than 260 hands-on environmental education programs for nearly 9,000 students. In addition, we developed remote learning lessons for teachers, students, and parents to extend learning outside the classroom. We reinforced learning about watershed health with a recreational component that creates lifelong interest in waters through fishing and conservation. Minnesota Trout Unlimited's (MNTU) instructors led nearly 70 introductory fishing skills programs for over 1,000 youth and their families. These clinics were made possible by partnerships with local governments and civic organizations, and numerous Trout Unlimited volunteers.

Approximately 10,000 students developed greater understanding of, and connections to, aquatic ecosystems, which will help them to make well informed decisions that positively impact water quality and watershed health.

PROJECT RESULTS USE AND DISSEMINATION
Our website was revamped with updated information about educational opportunities, including Trout in the Classroom and fishing skills programs. The Facebook and Instagram pages were started in 2018 and gained hundreds of followers during this project. A suite of youth educational videos and other resources were developed and are available online. Our team wrote education updates and youth series articles for all three MNTU newsletter editions publish each year. Thousands of hard copies of the newsletters were distributed to teachers for classroom use and/or to send home with students.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 05e Expanding River Watch Program on the Minnesota River With High School Teams - $100,000 TF

Ted Suss
Friends of the Minnesota Valley
6601 Auto Club Road
Bloomington, MN 55438

Phone: (507) 828-3377
Email: tedlsuss@gmail.com

Appropriation Language
$100,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Friends of the Minnesota Valley to expand a River Watch program on the Minnesota River to recruit at least 15 additional teams of high school students in monthly monitoring and reporting of water quality.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
With funding from the ENRTF, we were able to expand River Watch from four high school teams to 14 teams and recruited at least two additional teams to participate in future years. Through the program, approximately 250 students learned how to conduct water quality monitoring, the pollutants that affect water quality, how to operate monitoring equipment, and to report the data. Students learned sources of pollution and actions that can be taken to reduce future water pollution.

OVERALL PROJECT OUTCOME AND RESULTS

The River Watch program engaged high school students from18 high schools in lessons about surface water quality, students learned how to operate sophisticated electronic equipment to test water quality. Data collected was submitted to the Minnesota Pollution Control Agency through the Citizen Water Quality Monitoring program.

Although data collection is an important purpose of the River Watch program, providing students with a meaningful experiential learning opportunity that teaches them the importance of water quality is the primary purpose. River Watch participants learn more than just facts, they develop understanding about water quality they will carry with them for their entire lives. Based on student feedback, River Watch achieved this goal of a meaningful educational experience.

Another goal Friends of the Minnesota Valley hoped to accomplish with ENRTF funding was to grow our River Watch program from a trial program working with four teams to a program working with 15-20 teams. Through the use of ENRTF funding, Friends was able to develop high quality informational brochures, a website, and other supporting materials to promote the River Watch program. We succeeded by working with 18 different high schools and will begin the 2021-2022 school year with 16 teams participating in River Watch and other teams considering joining. Covid limitations significantly reduced our ability to take students directly to rivers for sampling during the 2021 school year, but desired program growth did occur.

A third objective was to raise public awareness of the River Watch program and public awareness of the water quality problems facing the Minnesota River. On several occasions, local news media covered student monitoring events. Public awareness of River Watch is well established and the program is set to continue in future years due to the foundation built during the three years that the program was funded by LCCMR.

The Minnesota River is widely seen as one of the most polluted rivers in Minnesota. Teaching today's high school students(tomorrows adult citizens and leaders) the seriousness of this problem, giving them the knowledge and understanding of the problem, and inculcating a desire to solve the problem will benefit the State of Minnesota as these young people move into positions in which their personal actions and the public decisions they make or influence lead to river water quality protections. As the River Watch program grows, an ever-growing number of young people will be motivated and equipped to "clean up" the Minnesota River.

The data collected to date and in the future will enable policy makers at the local and state level to make better informed decisions that will improve and protect water quality in the Minnesota River basin and downstream in the Mississippi River.

PROJECT RESULTS USE AND DISSEMINATION

Each time a River Watch Team conducted a water quality monitoring event, local news media including radio, newspapers, and television was informed and invited to provide coverage. Several local newspaper articles covering such events were published and at least one television story was broadcast.

The very process of recruiting River Watch teams involved communication with every secondary school administrator in the Minnesota River basin. These communications were often shared with local school boards as part of the participation approval process. Students and staff in River Watch have been invited

to speak at local service group meetings. Each communication included reference to LCCMR/ENRTF funding.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 05f Pollinator Ambassadors Program for Gardens - $250,000 TF

Elaine Evans
U of MN
1980 Folwell Ave, 219 Hodson Hall
St. Paul, MN 55108

Phone: (651) 644-1227
Email: evan0155@umn.edu
Web: https://www.beelab.umn.edu

Appropriation Language
$250,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to increase knowledge of pollinators in gardens and yards and improve pollinator habitat by expanding outreach, training, and tools for Minnesota communities as part of the Pollinator Ambassadors program. 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 Pollinator Ambassadors for Gardens program broadened pollinator education access across Minnesota, particularly to traditionally underserved audiences, through training 43 youth Pollinator Ambassadors and distributing 250 Pollinator Education Toolkits. Broader adoption of pollinator conservation action-steps will help Minnesotans conserve pollinator diversity, which will support food production, water quality, and healthy ecosystems.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesotans are aware of the importance of pollinators to healthy food systems and ecosystem health but lack prepared educators and education materials to provide action steps for pollinator conservation. The Pollinator Ambassadors Program for Gardens aimed to 1) provide direct training to youth to engage their communities in pollinator education and 2) create a Pollinator Education Toolkit with expert-designed materials that educators state-wide can use to teach pollinator conservation action steps. We have successfully trained 43 Pollinator Ambassadors between the ages of 14 and 18 through in-person and virtual workshops. Pollinator Ambassadors have directly engaged approximately 3,000 Minnesotans. We distributed 250 Pollinator Education Toolkits across Minnesota to 53 nature centers, 91 classroom educators, 33 Master Gardeners and Master Naturalists, 42 non-profits, 14 federal, state, or municipal agencies, and 17 University of Minnesota Extension programs. These Pollinator Education Toolkit holders estimate reaching 100,000 people annually. Many organizations receiving Pollinator Education Toolkits prioritize service to or primarily serve low-income audiences (40%), recent immigrants (15%), Latinx communities (15%), African American communities (13%), Asian American communities (9%), and Native American communities (9%). Toolkits are also available publicly through Inter Library Loan and check out at four University of Minnesota Extension and Outreach Centers across

Minnesota. Over 400 educators across the world have accessed the Digital Pollinator Education Toolkit with an estimated annual reach of 180,000. The Pollinator Ambassadors Program for Gardens has increased capacity to reach a broad geographic range of audiences in Minnesota, with youth trained in Big Stone, Hennepin, Ramsey, Wright, and Olmsted counties and toolkits with educators in 60 of Minnesota's 87 counties, as well as increasing reach to traditionally underserved audiences. Broader adoption of pollinator action steps by Minnesotans will help conserve pollinator diversity, which in turn will support food production, water quality, and healthy ecosystems.

PROJECT RESULTS USE AND DISSEMINATION
We have several resources that should be shared broadly. A summary of the impact of the Pollinator Ambassadors for Gardens program is available on the Bee Lab YouTube channel. The University of Minnesota Bee Lab website has a page dedicated to the Pollinators Ambassadors program. Pollinator Education Toolkits are available for checkout out through Interlibrary Loan and at the University West Central, North Central, Southwest and Rosemount Research & Outreach Centers. Digital Pollinator Education Toolkit resources are available to everyone who fills out our application form. We have created a "Learn to Use Pollinator Education Toolkits" video playlist to provide extra background, and a "Pollinator Ambassadors" video playlist to complement activities from the Toolkits. The Habitat Assessment Guide for Yards and Gardens is available as a pdf document.

Project Completed: 6/30/2022
FINAL REPORT
Habitat Assessment Guide for Pollinators in Yards, Gardens, and Parks - 12 pgs
Checklist of Actions - To Promote Pollinators In Yards, Gardens & Parks
A Bee Nest Round The Year
Bees or Wanna-Bees?
Four Actions to Help Pollinators
How are the Pollinators Doing?
Rare Minnesota Bees
Myths and Realities for Polinators
Abejas O Mimicas
Como Les Esta Yendo A Los Polinizadores
Cuatro Acciones Para Ayudar A Los Polinizadores
Mitos Y Realidades Sobre Los Polinizadores

Subd. 05g Morris Prairie Pollinator Demonstration Area and Education - $550,000 TF

Steven Poppe
U of MN - Morris
WC Research and Outreach Ctr
Morris, MN 56267

Phone: (320) 589-1711
Email: poppesr@morris.umn.edu
Web: http://www.wcroc.cfans.umn.edu

Appropriation Language
$550,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota

for the West Central Research and Outreach Center at Morris to restore 17 acres of native prairie for pollinators and to construct wayside shelters and kiosks along an existing trail to provide information to visitors on the importance of pollinators and native prairie ecosystems. 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 17 acres to a native prairie habitat to enhance the local ecosystem for beneficial pollinators and native species of plants. The project site also provides educational opportunities for visitors on how to protect or enhance native habitats and beneficial pollinators.

OVERALL PROJECT OUTCOME AND RESULTS
The Pomme de Terre River watershed area in west central Minnesota was once a sprawling prairie, home to beneficial pollinator species and prairie vegetation. Now, however, we've seen a devastating decline of beneficial pollinator species and a disruption to the remaining native prairie ecosystem due to land conversion to other uses. To address this concern, we worked with prairie restoration specialists to restore a 17-acre habitat in Morris, Minnesota. All non-native vegetation was removed, and a diversity of prairie plant seeds were seeded throughout the site to offer food sources for pollinators known to our region. Fifty Bur Oak trees were planted to create an oak savannah for improved wildlife habitat. Regular maintenance was conducted on the site to control both perennial and annual weeds, which allowed the prairie species to establish. The outcome was an improved landscape that supports bees, butterflies, and other beneficial pollinators as well as an enhanced ecosystem. The addition of native plants sequesters carbon and other air pollutants and filters runoff entering the watershed. Since restoration, biodiversity of plant and wildlife species has visibly increased. The native plant species are beginning to dominate over unwanted vegetation and attract a multitude of pollinator species.

Educational interpretation was installed throughout the demonstration site to encourage visitors to connect with the prairie habitat and learn how to create or enhance habitats on their own properties. We partnered with University of Minnesota Morris faculty and students to design, develop, and evaluate an interactive educational activity on pollinators and prairie restoration. The local high school uses the restoration site as an outdoor classroom to learn about beekeeping, pollinator health, and pollinator habitats.

PROJECT RESULTS USE AND DISSEMINATION
Two educational kiosks were installed on the site, along with two interpretive signs. Information available to the public at the kiosks includes why we need pollinators, the steps we've taken to restore the area, and the types of native pollinators in our region. A pamphlet from the Minnesota Department of Agriculture is available at the northern most kiosk. Interpretive signs along the trail include information about pesticide use in a pollinator friendly way and the environmental benefits of prairie restoration. Updates and articles about the project are available on the West Central Research and Outreach website.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 05h Expanding Nature Knowledge and Experience with New Interactive Exhibits at North Mississippi Regional Park - $500,000 TF

MaryLynn Pulscher
Minneapolis Parks and Recreation Board
3800 Bryant Ave S
Minneapolis, MN 55419

Phone: (612) 313-7784
Email: mpulscher@minneapolisparks.org
Web: http://www.minneapolisparks.org

Appropriation Language
$500,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Minneapolis Park and Recreation Board to develop new interactive exhibits at North Mississippi Regional Park to encourage the approximately 326,000 annual visitors to better understand and explore the river and surrounding natural area.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The new Nature in the City exhibit at North Mississippi Regional Park features compelling design with interactive components that spark curiosity about Nature, increase knowledge about Nature, entice visitors to explore the outdoors, and become better stewards of the environment.

OVERALL PROJECT OUTCOME AND RESULTS
Nestled between I-94 and the Mississippi River in north Minneapolis, North Mississippi Regional Park serves more than 300,000 annual visitors. Located within the park is the Carl Kroening Interpretive Center which featured an outdated and worn educational exhibit focused on human relationships to the Mississippi River as drinking water, transportation corridor, and job source. However, park staff discovered that what visitors really wanted was to learn more about the natural resources found in the park - the land, the water, animals, birds and insects - and connect with Nature in a hands-on, immersive way.

The overarching objective of the project is to educate and inspire park visitors so they can make better decisions to positively impact the natural world. Minneapolis Park & Recreation Board staff worked with Split Rock Studios (SRS) to imagine and develop content and components for a new educational exhibit titled Nature in the City. SRS then designed, fabricated, sculpted, and installed the landforms, interactives, super graphics, taxidermy, technology, signs and more. The exhibit features current research, compelling interpretation and visuals, and interactive components to spark wonder and curiosity about the Mississippi River, stormwater runoff, native plants and pollinators, wildlife and their adaptations to city living, plus migration, the Mississippi flyway, and more. Designed to foster repeat visitation, parts of the exhibit can change out seasonally, while others provide space to add stories and information in response to park visitor interests. The exhibits, along with programs led by staff, promote ways people can take action to benefit land and water. Park visitors are also encouraged to apply their new knowledge while exploring the park and contribute to citizen science field work.

PROJECT RESULTS USE AND DISSEMINATION
Due to the pandemic, the Kroening Interpretive Center remains closed to the public. When restrictions are lifted, staff look forward to welcoming the estimated 326,000 annual visitors to North Mississippi Regional Park to explore the new Nature in the City exhibit.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 05j Expanding the State's Reuse Economy to Conserve Natural Resources - $275,000 TF

Jenny Kedward
ReUse Minnesota
2446 University Ave W
St. Paul, MN 55114

Phone: (612) 352-9119
Email: info@reusemn.org
Web: https://www.reusemn.org/

Appropriation Language
$275,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with ReUSE Minnesota to provide outreach and technical assistance to communities and small businesses to create and expand opportunities for reusing, renting, and repairing consumer goods as an alternative to using new materials so solid-waste disposal and its impacts are measurably reduced and more local reuse jobs are created. Net income generated as part of this appropriation may be reinvested in the project if a plan for reinvestment is approved in the work plan.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
ReUSE MN connected businesses and consumers to organizations providing reuse, repair, and rental services through two conferences and 24 educational events. Research conducted revealed the Minnesota reuse sector makes up 1/3 of the retail economy. By avoiding new products, reuse saves 67 billion gallons of freshwater from being used each year.

OVERALL PROJECT OUTCOME AND RESULTS
Current practices of throwing away usable items and unnecessarily producing new goods depletes finite natural resources and pollutes our environment at an unsustainable pace. Reuse helps slow this process and keeps materials and products in use longer. The goal for this project was to promote the benefits of reuse, repair, and rental, including the organizations providing these services. Encouraging consumers to reuse results in more sustainable consumption patterns and supports the local economy.

LCCMR funding allowed ReUSE MN, a small, volunteer-run non-profit, to hire a management company to streamline organizational processes, update our website, and improve our membership structure.

Over the past two years, we hosted two conferences that highlighted reuse innovations, programs, policies, and research. The 2019 conference was the state’s first reuse-focused conference, and welcomed 118 attendees. The 2020 virtual national conference saw 212 attendees representing 23 states and 3 Canadian provinces. ReUSE MN also hosted 20 webinars and educational sessions, and staffed booths/presented about reuse at 17 partner-hosted events.

The organization grew its reuse network of nonprofits, businesses, policymakers, educators, and consumers with paid memberships increasing to 205 – a nearly 7-fold increase over the grant period.

Using survey responses and purchased business data, ReUSE MN created a report summarizing the environmental, economic, and social impacts of reuse. Minnesota's reuse sectors:

- make up 1/3 of the retail economy, generating $5.8 billion (2017).
- avoid over 2.7 million metric tons of greenhouse gas emissions and 67 billion gallons of freshwater extraction per year (ground or surface water sources) from products that would have been newly manufactured.

Reuse organizations play an important role in communities, keeping money and services local, offering spaces for learning and skills-building, and bringing like-minded individuals together around shared goals. Data and stories gathered throughout this grant will help advocate for Minnesota reuse organizations and show the importance of extending the life of our belongings and protecting the state's resources.

PROJECT RESULTS USE AND DISSEMINATION
ReUSE Minnesota provides regular updates and resources through monthly e-newsletters and social media. We reached more than 2,100 people through 36 educational sessions, member meetings, and two conferences. The ReUSE MN website acts as a directory for rental, repair, and reuse businesses as well as a resource for events and news about the reuse economy.

The final measurement and methodology report is housed on the ReUSE MN website. The new Reuse Impact map provides an interactive look at how reuse benefits the economy and environment across the state and by county. Nearly 100 listeners heard about the impact study results on a webinar. Results have already helped start conversations in counties that want to boost their reuse business sector to reduce waste.

Project Completed: 12/31/2020
FINAL REPORT

Subd. 05k Expand Materials Reuse and Recycling Jobs Program - $800,000 TF

Steve Thomas
The Network for Better Futures (D/B/A) Better Futures Minnesota
PO Box 6596
Minneapolis, MN 55406

Phone: (612) 455-6133
Email: sthomas@betterfutures.net
Web: https://www.betterfuturesminnesota.com

Appropriation Language
$665,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Better Futures Minnesota, in cooperation with the Northwest Indian Community Development Corporation, and $135,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Natural Resources Research Institute in Duluth to expand building deconstruction and material-reuse practices and jobs in partnership with counties, tribes, and

municipalities statewide and to document the environmental, health, and economic benefits of these practices. Net income generated by Better Futures as part of this or a previous related appropriation from the environment and natural resources trust fund may be reinvested in the project if a plan for reinvestment is approved in the work plan.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

This project funded: the deconstruction of 29 properties; 10.5 FTE jobs; transitional employment of 200 people; a reuse project at a county landfill; and the promotion of deconstruction and material reuse throughout the State. The project generated close to net zero emissions by diverting 80% of 8,000,000 pounds of material from landfills.

OVERALL PROJECT OUTCOME AND RESULTS

This project supported the growth of building material stewardship, an essential and viable alternative to burying 70% of the State's building waste in landfills. Practical alternatives to dumping are needed to avert the serious health, financial, and environmental costs of landfill use.

Three activities were completed. First, by providing advice and assistance to counties, a deconstruction incentive grant program for homeowners in Hennepin County was implemented and a diversion/reuse program at the Becker County landfill was established.

Second, through presentations and outreach the partners made significant progress in making the reuse and recycling of building materials a preferred practice statewide. One result is the Sustainable Building Materials stakeholder group with staff support from the MPCA. This work group is focused on informing rule changes for landfills, expanding deconstruction work in the State, and expanding the marketplace for the reuse of materials.

This outreach was combined with deconstructing 29 properties in 22 communities, launching a diversion and reuse program at a county landfill, and training and offering transitional employment for 200 people. The results of this effort - types and value of materials harvested and reused; jobs created; and the benefits for our air, water, and land - demonstrated to many audiences the value of this project.

The third activity focused on documenting that 80% (3,117 tons or 6,234,000 pounds) of the 4,000 tons collected was diverted from landfills. The most beneficial environmental outcome is that 346 tons or 9% of the material was reused.

Overall, the benefits of the deconstruction and reuse, as an alternative to demolition, are broad and generous. Project data shows deconstruction generates 70% less emissions than demolition. This project also approached net zero emissions per ton of material collected: .63 metric tons of CO2 for deconstruction compared to 2.23 metric tons of CO2 for demolition.

This project can inform economic development and healthy environmental practices Statewide. The formula is practical: take apart and reuse buildings rather than dumping them in landfills and begin diverting reusable materials at landfills. These new methods create more jobs, provide quality materials for consumers, and dramatically reduces harmful pollutants.

PROJECT RESULTS USE AND DISSEMINATION

The highlights of the partners' many and varied dissemination efforts included: an opportunity to introduce building material stewardship and deconstruction practices to more than 150 government,

tribal, and business owners during statewide MPCA stakeholder meetings; an opportunity to describe this projects' value and impact to an international audience during a "virtual" conference sponsored by the Ellen McArthur Foundation in London, England; and, a presentation at the 2021 Environmental Initiative awards ceremony (Better Futures and Becker County received the 2021 Rural Innovation Award).

The partner's deconstruction pilot with St Louis County generated opportunities to promote the benefits and impact of deconstruction and material reuse.

Articles on this project were included in the Duluth Monitor, WDIO Radio, Duluth News Tribune, FOX21, and KBJR6.

Becker County staff created a significant number of followers (over 2500) on Facebook Marketplace. This site along with Craig's List are effective venues for promoting the reuse pilot and promoting sales events. Staff also promote reuse on a local weekly radio show.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 06 Aquatic and Terrestrial Invasive Species

Subd. 06b Palmer Amaranth Detection and Eradication Continuation - $431,000 TF

Monika Chandler
Minnesota Department of Agriculture
625 Robert St N
St. Paul, MN 55155

Phone: (651) 201-6537
Email: monika.chandler@state.mn.us

Appropriation Language
$431,000 the second year is from the trust fund to the commissioner of agriculture to continue to monitor, ground survey, and control Palmer amaranth primarily in conservation plantings and to develop and implement aerial-survey methods to prevent infestation and protect prairies, other natural areas, and agricultural crops.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Palmer amaranth is an aggressive weed that is expensive and damaging to control. It was found as a contaminant in a small number of conservation planting seed mixes sold in Minnesota. Rapid response to the situation resulted in Palmer amaranth eradication from impacted conservation plantings.

OVERALL PROJECT OUTCOME AND RESULTS
Palmer amaranth is an invasive plant that threatens row crop production and prairies. In 2016, it was found in a small number of conservation planting seed mixes. There were concerns that Palmer amaranth would spread to nearby crop fields and cause high yield losses, up to 91% in corn and 78% in soybeans. Palmer amaranth can be resistant to multiple herbicides making it difficult to control. There

was a lot of concern about the conservation planting pathway for Palmer amaranth and it was declared an agricultural emergency by the commissioner of agriculture.
This project enabled rapid response to the situation as it unfolded.

- Palmer amaranth was controlled in the field by Conservation Corps Minnesota using propane torches, prescribed fire and hand pulling. As a result, Palmer amaranth was eradicated from all impacted conservation plantings. There were 92 infestations (some in crop fields) of which 67 were eradicated, 13 were negative (no Palmer found in field planted with contaminated seed mix) and 12 are active infestations in crop fields that MDA will continue to monitor.
    - Intensive infestation monitoring was required to achieve this successful outcome.
- Drones were utilized to help look for Palmer amaranth in large fields. This work with drones was experimental and led by the University of Minnesota's UAV Lab. We learned much that can be applied for future aerial survey efforts.
    - MDA now uses a drone for aerial survey.

Palmer amaranth control efforts were so effective that some Conservation Corps Minnesota funding could be diverted to control other priority target species infestations including black swallow-wort, common teasel, cutleaf teasel, Japanese hops, oriental bittersweet, poison hemlock and knotweeds.

PROJECT RESULTS USE AND DISSEMINATION
Presentations, articles, and a paper were the primary dissemination means. There were 40 presentations, trainings or updates about Palmer amaranth and this project. In trainings, we used resources developed for the ENRTF project Elimination of Target Invasive Plant Species including 3D printed models of Palmer amaranth seedlings, pressed plant samples, and large format printed displays. Two popular press articles were written and sent to outstate media. Our paper Timeline of Palmer amaranth invasion and eradication in Minnesota was open access published in Weed Technology. To date, it was accessed via HTML by 741 and via PDF by 4,580.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 06c Evaluate Control Methods for Invasive Hybrid Cattails - Research Project - $131,000 TF

Steve Windels
Voyageurs National Park
360 Hwy 11 E
International Falls, MN 56649

Phone: (218) 283-6692
Email: steve_windels@nps.gov

Appropriation Language
$131,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Voyageurs National Park to evaluate the effectiveness of mechanical harvesting and managing muskrat populations to remove exotic hybrid cattails and restore fish and wildlife habitat in

Minnesota wetlands. 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
Invasive hybrid cattails can be effectively controlled by mechanical treatments, creating space for native plants like wild rice and other native aquatic plants, and enhancing habitat for wetland-loving wildlife like muskrats, mink, otters, bitterns, rails, grebes, and more.

OVERALL PROJECT OUTCOME AND RESULTS
Invasive hybrid cattails are rapidly expanding throughout Minnesota's wetlands. Hybrid cattails grow in dense stands that crowd out native plant species and create single species stands that can degrade both fish and wildlife habitat and negatively impacts biodiversity and wetland function. Starting in 2016, Park staff, securing both state and federal funding, initiated the Voyageurs Wetland Restoration Project to restore wetlands within the large lakes of the park that have been infested by invasive hybrid cattails. Through this LCCMR grant, we documented that we achieved reductions of invasive hybrid cattail cover from all six mechanical treatments that were tested. Lethal treatments showed the greatest reduction in cattail coverage with all treatments, showing approximately a 90% reduction in cattail cover up to 3-years post-treatment. Treatment of cattails increased cover and diversity of native wetland plants across all treatment types, which we lumped into 4 functional plant groups: rushes, sedges, grasses, and herbaceous plants. Our project represented the first attempt to translocate muskrats and assess post-translocation survival and movements. Additionally, our project was the first to experimentally investigate feeding preferences of muskrats and also quantify immediate foraging effects of translocated muskrat populations on T. x glauca coverage in wetlands. We found that translocated muskrats quickly established home ranges and that survival of post-translocated muskrats was similar to reported survival estimates of other established muskrat populations. Overall, our results suggest that muskrat translocations may be a viable option to re-establish or temporarily increase abundances of muskrat populations, especially in areas with a healthy beaver population. Even though we showed that muskrats do eat invasive hybrid cattails, we do not believe that muskrat densities in our area can be elevated to a high enough density for multiple years to where stands of invasive hybrid cattail can be eliminated or even noticeably reduced in abundance.
PROJECT RESULTS USE AND DISSEMINATION
This collaboration between the National Park Service's Voyageurs Wetland Restoration Project and Kansas State University produced five scientific papers and other reports. Our findings, though many are still preliminary, have influenced wetland restoration techniques throughout the U.S. and Canada through our presentations at local, state, and national scientific conferences; through our outreach efforts via print and online media; and through one-on-one consultations with others working on wetland restoration.

Project Completed: 6/30/2022
FINAL REPORT
Supplementary Materials for "Evaluate Control Methods for Invasive Hybrid Cattails" - 85 pgs

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Subd. 06d Developing RNA Interference to Control Zebra Mussels - $500,000 TF

Christopher Merkes
U.S. Geological Survey

2630 Fanta Reed Rd
La Crosse, WI 54603

Phone: (608) 781-6316
Email: cmerkes@usgs.gov
Web: https://www.usgs.gov/staff-profiles/chris-m-merkes

Appropriation Language
$500,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the United States Geological Survey to develop a genetic control tool that exploits the natural process of RNA silencing to specifically target and effectively control zebra mussels without affecting other species or causing other nontarget effects. 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 project did not occur due to challenges the entity encountered receiving state funds.

Project Completed: 6/30/2021

Subd. 06e Install and Evaluate an Invasive Carp Deterrent for Mississippi River Locks and Dams - $998,000 TF

Peter Sorensen
U of MN - AIS Center
1980 Folwell Ave
St. Paul, MN 55108

Phone: (612) 624-4997
Email: soren003@umn.edu
Web: http://fwcb.cfans.umn.edu/sorensen/

Appropriation Language
$998,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with the United States Army Corps of Engineers and the United States Fish and Wildlife Service to install, evaluate, and optimize a system in Mississippi River locks and dams to deter passage of invasive carp without negatively impacting native fish and to evaluate the ability of predator fish in the pools above the locks and dams to consume young carp. The project must conduct a cost comparison of equipment purchase versus lease options and choose the most effective option. 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 discovered that even when equipped with a sound-light deterrent, Lock and Dam 8 has little promise to stop invasive carp but that Lock and Dam 5 could stop over 99% of all carp if equipped with a sound-light deterrent that includes a bubble curtain.

OVERALL PROJECT OUTCOME AND RESULTS
The purpose of our project was to determine how to stop invasive carp. Because all carp must pass through locks-and-dams we focused on these structures, focusing on Lock and Dam 8 (LD8) near the Iowa border. We specifically examined whether and how carp could be stopped at LD8 by adjusting its spillway gates, installing a sound-light deterrent in its lock, and managing native fish predators in its vicinity. While we found that this combination has little promise at LD8, nearly all carp could be stopped upstream at LD5 using a variant of it, sparing Lake Pepin and most of the state. Insight came from several aspects of our research. First, by releasing acoustically-tagged common carp at biweekly intervals and tracking their movements upstream through LD8, we discovered that carp passage through spillway gates only occurs at high discharges as predicted by a fish passage model -- proving that LD8 is a poor location to stop carp because its gates open infrequently, but that LD5 is an excellent location because its gates do. Second, we found that carp passage through locks is predictably low, meaning that the lock at LD5 is an excellent location to install a deterrent because of this LD's low spillway passage rates. Third, while we found that a sound-light deterrent was ineffective at blocking carp, a sound-light-bubbling system (BAFF) is. An engineering analysis supported using a BAFF at LD5. Fourth, when we examined whether native predatory fishes might control invasive carp, we discovered no support: no common predator feeds on fish (carp) eggs and floodplain predators do not favor their young. Finally, we created a numeric model which showed that a BAFF at LD5, coupled with spillway optimization, and carp removal at that site would stop 99.6% of all carp in Minnesota – a solution has been identified.

PROJECT RESULTS USE AND DISSEMINATION
Our findings on carp deterrents are being used by the US Fish and Wildlife Service to test a bioacoustic fish fence. Our findings have been widely disseminated. A recent summary of the project was presented at a carp forum: Carp Forum. In addition, we presented our findings at several public (ex. 2019 Stop Carp Forum), scientific (ex. Midwest Fish and Wildlife meetings) and agency level meetings (ex. annual Mississippi River ANS Task Force Meetings). We have published 3 scientific peer-reviewed articles and have 2 in review. The StarTribune covered our project twice in front page articles as did Minnesota Outdoors.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 06f Determining Risk of a Toxic Alga in Minnesota Lakes - Research Project - $200,000 TF

Adam Heathcote
Science Museum of Minnesota - St. Croix Research Station
16910 152nd Street N
Marine on St. Croix, MN 55047

Phone: (651) 433-5953
Email: aheathcote@smm.org
Web: https://www.smm.org/scwrs

Appropriation Language
$200,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix

Watershed Research Station to determine the historical distribution, abundance, and toxicity of the invasive blue-green alga, Cylindrospermopsis raciborskii, in about 20 lakes across Minnesota and inform managers and the public about the alga's spread and health risks. 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 produced the first systematic survey of Minnesota's Sentinel Lakes for the toxic invasive algae Cylindrospermopsis raciborskii (Cylindro). Cylindro was contained to the 2 lakes where it was initially found and did not produce toxins in measurable amounts. Sediment records indicated that Cylindro has appeared in the last 10 years and has not spread statewide.

OVERALL PROJECT OUTCOME AND RESULTS

Cylindro is a subtropical invasive species of Cyanobacteria that has been invading lakes in the Upper Midwest since the early 2000s. Cylindro is of particular concern because it is known to produce a potent liver toxin and the presence of its blooms can be difficult to identify. Cylindro was first discovered in two Minnesota lakes in 2013, and that discovery led to the design of this statewide survey of the Minnesota Sentinel Lakes to better understand the spread and invasion history of this species. Our monitoring results, based on DNA and microscopy, show that Cylindro is currently limited to the two lakes where it was initially found, and sediment cores indicate that it has been present in those lakes for under 10 years. Additionally, even in lakes where Cylindro was present, there was no evidence of toxin production in detectable amounts, minimizing the public and wildlife health threat of this species. Thankfully, these results suggest that the threat of Cylindro invasion in Minnesota lakes is currently low, though continued monitoring for this species is important given the trend of warming lake waters across the state.

PROJECT RESULTS USE AND DISSEMINATION

We have shared the progress and results from this project widely over the duration of the project. This includes both articles written by our staff, shared with traditional and social media, and peer reviewed papers. These efforts are summarized below in chronological order:

- Invisible" species of exotic algae threatens to poison Minnesota lakes, posted to SMM.org on 11/6/2018, (PDF attached in supplemental materials)
- "Conditions ripe for a record number of algae blooms", Minnesota Public Radio Climate Cast segment on 7/19/2019
- "Why good algae go bad", talk at the Marine Community Library by Adam Heathcote on 7/14/2019, picture of event on Twitter
- Adam Heathcote Co-chaired special session on Harmful Algal Blooms at the Minnesota Water Conference and organized a panel of experts to take questions from conference attendees in St. Paul, MN on 10/16/2019
- During the pandemic we provided information on harmful algal blooms for the public on the Science Museum website in our "Learn From Home" section, posted on 7/7/2020
- Preliminary results from this study were presented to the Minnesota Inter-agency HABs group at their Winter Workshop on 1/25/2021. Attendees includes representatives from the Minnesota DNR, MPCA, MDH and the MVMA
- Results from this study were published in the peer-reviewed journal PLOS ONE on 3/21/2022. PDF of paper is attached in the supplemental materials

Project Completed: 6/30/2022

FINAL REPORT
Diversity and distribution of sediment bacteria across an ecological and trophic gradient - 20 pgs

Subd. 07 Air Quality and Renewable Energy

Subd. 07a Develop Solar Window Concentrators for Electricity - $350,000 TF

Uwe Kortshagen
U of MN
111 Church St SE
Minneapolis, MN 55455

Phone: (612) 625-4028
Email: kortshagen@umn.edu

Appropriation Language
$350,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop, evaluate, and optimize thin film silicon-based luminescent solar window concentrators in order to produce inexpensive, clean energy and reduce air pollution. This appropriation is subject to Minnesota Statutes, section 116P.10. 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 demonstrated the potential of semi-transparent “solar windows” based on silicon nanocrystals to produce carbon-free, renewable electricity. Greenhouses were identified as an attractive application. As greenhouses are becoming more widespread in Minnesota, this project will contribute to reducing their environmental footprint in terms of energy and water usage.

OVERALL PROJECT OUTCOME AND RESULTS
This project focused on exploring inexpensive “solar windows” that are transparent and produce clean electricity. Solar windows are based on solar concentrators using highly luminescent nanometer-sized silicon crystals, a technology developed at the University of Minnesota. The silicon crystals, embedded in or coated onto the windowpane, absorb harmful-to-humans ultraviolet and blue light and turn it into red light, which is guided by internal reflection to the edge of the window pane, where it is concentrated onto a small-area solar cell.

Over the course of this project, the project team learned that these solar windows are of particular interest to greenhouses. While being partially transparent, they can produce electricity while not impeding or even enhancing plant growth. The project team initially focused on exploring experimental prototypes of the technology. Based on characterization of these prototypes, models were developed that allow us to predict the performance of larger scale devices. These models were extended into a comprehensive simulation tool that can describe the renewable electricity produced by a solar greenhouse, the light available for plant growth, as well as the overall energy balance of a greenhouse.

For Minnesotans, results of this research may have significant future benefits. Greenhouses allow us to produce certain crops locally that are hard to grow in open-field farming in Minnesota. Locally grown

produce is fresher and reduces the emissions associated with shipping of produce across the county. Greenhouses also only use a fraction of the water and fertilizer that is required in open-field farming. While generally energy-intensive, this research project has pointed the way to reduce the energy consumption of greenhouses through solar windows.

PROJECT RESULTS USE AND DISSEMINATION
Results of this research have been published in the scientific literature and presented at conferences. Three scientific papers were published related to:

- The influence of scattering on the performance of silicon luminescent solar concentrators
- The demonstration of silicon thin film luminescent solar concentrators
- The application of silicon luminescent solar concentrators to agrivoltais

Among the conference presentations presented by graduate students working on this project, one was chosen for the "best presentation" award.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 07b Demonstrations for Community-Scale Storage System for Renewable Energy - $550,000 TF

Ellen Anderson
U of MN - I on E
1954 Buford Ave, 229 19th Avenue S
Minneapolis, MN 55455

Phone: (612) 625-1981
Email: ellena@umn.edu

Appropriation Language
$550,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to install, demonstrate, and evaluate three community-scale storage systems for renewable energy and develop a guidebook on storing renewable energy for statewide use. 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 University of Minnesota's Institute on the Environment with Renewable Energy Partners, Red Lake Tribal Government Center, and University of Minnesota-Morris, demonstrated community-scale storage for renewable energy, including microgrids and battery systems. This project expanded our knowledge of leading-edge technology, shared lessons learned on battery acquisition, permitting, and installation, and advanced energy justice.

OVERALL PROJECT OUTCOME AND RESULTS
More cities, campuses, nonprofit entities, and businesses across Minnesota are using wind and solar technology to produce cleaner energy. To reach high levels of renewable energy, significantly reduce their emissions, and achieve energy independence, they will need to include energy storage in their energy systems. Currently there are few examples of "community scale" energy storage projects, and

often these entities lack the technical knowledge needed to select and optimize the best energy storage system. The overall goal of this project is to expand community-based, locally-produced renewable energy and reduce air emissions to improve the environment, under the LCCMR's funding priority "Air Quality, Climate Change, and Renewable Energy".

This project included three activities. First, we produced an "Community-Scale Energy Storage Guide" that describes both the operation of the US electricity grid with renewable energy and battery storage and different battery storage technologies and installation steps, using the sites as case studies. Second, we selected sites - Renewable Energy Partners, Red Lake Tribal Government Center, and University of Minnesota-Morris - and worked with them, using the guidebook research, to identify and acquire the optimal battery technology to meet site needs and provide technical assistance on design, permitting, and battery installation. At this stage, Renewable Energy Partners has a fully functional and tested battery - it will be complete when insurance is registered with Xcel Energy; Red Lake Tribal Government Center is completed; and University of Minnesota-Morris has the battery and installation components finalized and will proceed with installation once it receives permits. Third, given COVID-19, this project pivoted to develop a virtual site that includes highlights of the three demonstration sites, interviews on the benefits of battery storage, and webinars on battery storage lessons learned. Overall, this project expanded our knowledge of leading-edge technology, shared lessons learned on battery acquisition, permitting, and installation, and advanced energy justice.

PROJECT RESULTS USE AND DISSEMINATION
The project team created a "virtual site visit" that highlights the three demonstration sites and and presents interviews with the Project Partners to get the full scope of how the storage system was implemented.

We created a two part webinar that took a deep-dive into battery storage by conducting a panel discussion with industry experts, seminars and workshops.

We published an Energy Storage guidebook and highlighted this downloadable, user friendly publication at the CERTS events, Energy and Equity workshop, and with the Energy Storage Advisory Committee.

Published Videos on the IonE YouTube page:
Community-Scale Battery Energy Storage in Minnesota https://www.youtube.com/watch?v=RpNs6rvGKCI
Community-Scale Energy Storage: How does it work? https://www.youtube.com/watch?v=QjTjuJAtrxA

Project Completed: 6/30/2022
FINAL REPORT

Subd. 07c Develop Inexpensive Energy from Simple Roll-to-Roll Manufacturing - $300,000 TF

Tianhong Cui
U of MN
111 Church St SE
Minneapolis, MN 55455

Phone: (612) 626-1636
Email: tcui@me.umn.edu

Appropriation Language
$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop inexpensive, high-efficiency solar energy with simple roll-to-roll advanced manufacturing technology, using new materials such as perovskite to make solar cells. This appropriation is subject to Minnesota Statutes, section 116P.10. 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
Perovskite solar cells and modules were fabricated via two-step deposition method, hybrid chemical vapor deposition and air blade deposition, to produce electricity from free clean solar energy, which could reduce the dependency on the non-renewable energy usage and provide green environment and habitats for both residency and wildlife of Minnesota.

OVERALL PROJECT OUTCOME AND RESULTS
Perovskite material is a promising candidate for the next generation of solar cells with high efficiency and significantly lower cost than silicon solar cells. Potential use of thin film perovskite solar cells may revolutionize the current solar industry to produce clean renewable energy. We met the final objective of this project by developing methods for roll-to-roll manufacturing, including hybrid chemical vapor deposition and air blade deposition. More specifically, chemical vapor deposition processes were optimized, and air blade coating system was developed based on a 3D printer. Perovskite solar cell compositions, structures, and additives were also investigated and optimized to enhance the performance. We developed flexible perovskite solar cells on PEN substrates, which are compatible with the roll-to-roll process, and which show an efficiency of 13.3% via chemical vapor deposition method. We also produced a device with power conversion efficiency of 13.82% via air blade and chemical vapor deposition methods, and we fabricated and field tested 5 cm x 5 cm perovskite solar modules with an active area of 18 cm2square centimeters. The outcomes from this project contribute to the development of next generation photovoltaic industry and help researchers better understand the nature of the perovskite solar cells. By utilizing clean solar energy more efficiently via perovskite solar cells, the dependency on non-renewable energies and pollution may be reduced. Cheap and clean electricity produced from perovskite solar cells via the developed roll-to-roll compatible methods demonstrated during this project may further benefit the residents of Minnesota. By harvesting green solar energy more efficiently and economically.

PROJECT RESULTS USE AND DISSEMINATION
The findings were disseminated through the following publications in archived journals.

1. Rui Zhu, Xiangyang Wei, Gongnan Xie, Terrence Simon, and Tianhong Cui. "Numerical simulation of vapor deposition process of perovskite solar cells: The influence of methylammonium iodide vapor flow to perovskite growth." Journal of Solar Energy Engineering 143, no. 1 (2021).
2. Xiangyang Wei, Yangke Peng, Gaoshan Jing, Terrence Simon, and Tianhong Cui, “High Performance Perovskite Solar Cells Fabricated by a Hybrid Physical-Chemical Vapor Deposition”, ASME Journal of Solar Energy Engineering, Vol. 143, No. 4, 2021: 041006

3. Wei, Xiangyang, Yanke Peng, Gaoshan Jing, and Tianhong Cui. "Planar structured perovskite solar cells by hybrid physical chemical vapor deposition with optimized perovskite film thickness." Japanese Journal of Applied Physics 57, no. 5 (2018): 052301.

Project Completed: 6/30/2022
FINAL REPORT
Numerial Simulation of Vapor Deposition Process of Perovskite Solar Cells: The Influence of Methylammonium Iodide Vapor Flow to Perovskite Growth
High-Performance Perovskite Solar Cells Fabricated by a Hybrid Physical-Chemical Vapor Deposition

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

Subd. 08a Nongame Wildlife Program Acceleration - $220,000 TF

Kristin Hall
MN DNR
500 Lafayette Rd, Box 25
St. Paul, MN 55155

Phone: (651) 259-5104
Email: Kristin.hall@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$220,000 the second year is from the trust fund to the commissioner of natural resources to accelerate the nongame wildlife program including rare wildlife data collection, habitat management, collaborative land protection, conservation education, and a new emphasis on promoting nature tourism to benefit wildlife, visitors, and rural communities.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Funds from this grant helped us prioritize collaborative efforts in our Conservation Focus Areas. We successfully conducted 10 habitat improvement projects on over 200 acres for multiple Species in Greatest Conservation Need including: bottomland forest songbirds, prairie pollinators, Blanding's turtles, and oak savanna dependent species.

OVERALL PROJECT OUTCOME AND RESULTS
Results of this project can be broken down into three separate categories: habitat work, monitoring efforts and research. We surpassed our goals for the habitat restoration piece of this grant mainly due to the partnership aspect of Conservation Focus Areas. We were able to provide partial funding that leveraged broader participation in conservation actions. In total, this project enabled us to:

- plant 765 sapling trees in bottlomland forest habitat to help with reforestation efforts,
- plant 6,000 oak saplings in oak savanna habitat on 17 acres at Meadow Brook WMA,
- conduct prairie forb inter-seed plantings on 45 acres of prairie grassland at three different locations,
- contribute to 102 acres or prescribed fire management to reduce succession and overgrowth of woody vegetation in grasslands,

- restore a sandy shoreline for turtle nesting habitat.

All activities took place in at least one of the four activated CFAs (see map: Conservation Focus Areas (CFA) Status 2015-205 MN Wildlife Action Plan).

An important component of conducting habitat improvement work is monitoring the species response to management. These efforts were focused primarily on prairie habitat restoration activities in the southwest and southeast potion of the state. Both flora and fauna response has been measured prior to the restoration activity, during the establishment of the restoration and post management. These data will provide managers with information on ways to potentially adapt their management practices to better accommodate the species the habitat restoration is meant to benefit.

Research and monitoring are a top priority for the Nongame Wildlife Program, which uses status and trend data to determine the protection status of many nongame species. This grant helped us to conduct a pilot study for a new research project to better understand the recent declines of American kestrels. The pilot efforts resulted in a full scale project proposal for a federal grant which was awarded in spring of 2021.

PROJECT RESULTS USE AND DISSEMINATION
Conservation Focus Areas are one of the main implementation tools in our State Wildlife Action Plan and we celebrate the work being done throughout the CFA network in many of our communications. Our Nongame Wildlife Program Facebook page has featured some of the CFA habitat projects as well as the kestrel research. We have also created a 34 page, Wildlife Action Plan 5-year Report, featuring highlights on how the plan is funded and the work we do. This report will be available to the public as well as our supporters to provide a fun "behind the scenes" look at how our program operates.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 08b Develop BioMulch to Replace Plastic Soil Covering in Vegetable and Fruit Production to Increase Yield and Reduce Waste - $310,000 TF

Paulo Pagliari
U of MN - Lamberton
23669 130th Street
Lamberton, MN 56152

Phone: (507) 752-5065
Email: pagli005@umn.edu

Appropriation Language
$310,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop and test the performance of biodegradable biomulch to increase yield, conserve water, suppress weeds and pests, add nutrients to the soil, and replace large amounts of nonrecyclable and nondegradable plastic used in vegetable and fruit production. 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 was used to develop a biodegradable product that can be used to replace plastic mulch used in vegetable production. The results of research showed that the current formulation of BioMulch worked as expected for watermelon and zucchini; and underperformed (yield was reduced) for tomatoes, peppers, and strawberry.

OVERALL PROJECT OUTCOME AND RESULTS
This project was used to develop a biodegradable product, BioMulch, that can be used to replace plastic mulch used in vegetable production in MN. Plastic mulch cause environmental pollution as it slowly breaks down and creates pollutants such as micro and nanoplastics. Micro and nanoplastic have been proven to be endocrine disruptors and also cause severe health issues to human, animals, and aquatic life. Our intent with this project was to develop a biodegradable product which would replace plastic. Field trials were set up at the University of Minnesota Research and Outreach center at Lamberton. The BioMulch was tested on bell peppers, tomatoes, strawberry, watermelon, and zucchini. Our main goals with this project were to test the efficacy of BioMulch on preventing weeds from emerging and growing and keep the soil moist in comparison with plastic mulch. The results of our project showed that a biodegradable product can be safely created and used to replace plastic mulch used in vegetable production. Yield for watermelon and zucchini were similar between plastic cover and BioMulch; however, yield of tomatoes, peppers, and strawberry were reduced with the use of BioMulch. This management practice should minimize the agricultural footprint on the environment by minimizing the amount of waste being produced in Minnesota by vegetable producers. The use of a biodegradable soil cover means that at the end of the season a simple tillage practice can incorporate the soil cover into the soil and eliminate the waste currently being produced with plastic. Therefore, Minnesotans could benefit from this project by having lower amounts of plastic being used in vegetable production, lower amounts of micro and nanoplastic being created as plastic covers brake-down, and as a result cleaner air, soil, and water. In addition to, healthier Minnesota grown foods.

PROJECT RESULTS USE AND DISSEMINATION
The results of this project have been disseminated to growers that have attended Extension events at the Southwest Research and Outreach Center (SWROC) from 2021 to Summer 2022. The last phase of the research project was completed in June 2022 and now we are working on Extension materials which will be posted on the SWROC nutrient management website. Technology commercialization efforts continue at AURI.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 08c Develop Market-Based Alternatives for Perennial Crops to Benefit Water Quality and Wildlife - $150,000 TF

Jason Ulrich
Science Museum of Minnesota
16910 152nd St N
Marine on St Croix, MN 55047

Phone: (651) 433-5953 x28
Email: julrich@smm.org

Appropriation Language
$150,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix Watershed Research Station to design and evaluate at least six market-based scenarios for perennial cropping systems in Minnesota, including technological and economic feasibility, and estimate their potential to improve water quality and provide wildlife habitat. 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 project researched using different types of market incentives to develop policies and programs to fund putting more perennial lands in Minnesota's agricultural areas to benefit water quality and wildlife habitat.

OVERALL PROJECT OUTCOME AND RESULTS
Although as a state we've spent millions of dollars on conservation, the health of our streams and lakes has not improved in most of Minnesota's agricultural areas. At the same time, populations of songbirds, pheasants, bees, and monarch butterflies have continued to decline because of a loss of grassland habitat. The main reason for these issues is the continued loss of grassland to planting row crops like corn and soybeans. Reversing this loss is very difficult because of the high cost required to take profitable cropland out of production without affecting a farmer's bottom-line. In this project we researched new ways to restore our waterways and habitat by economically replacing typical row crops with grass and perennial crops by creating new market incentives. For example, what if a solar company could be paid an incentive by a publicly funded program to place solar arrays on small areas of corn fields near the edges of streams? A subsidy would be paid to the solar companies to install the array and the farmer could grow forage grass for grazing sheep underneath them. This way the farmer gets paid a fair rental rate for having the array on their property and could collect additional income from the livestock, while the solar company has an incentive to spend more to install and maintain the array. Our objective in this project was to research solutions such as these, estimating how much they would cost, and how a program or a policy would have to be structured to pay for them. We investigated several incentive programs and found that economically practical programs are possible right now with the right policies to support them. Our research provides a valuable starting point for policy makers to start thinking about new creative, economical ways to help restore the health of our waterways and grassland habitats.

PROJECT RESULTS USE AND DISSEMINATION
The work has been presented to agencies such as the Minnesota DNR and at several Science Museum member events. Finally, the project team was instrumental in organizing and leading the highly successful AgroEcology Summit in Windom, MN in August 2019, where the project work was presented over several hours to more than one hundred attendees. The concepts of using markets to drive adoption of perennial crops/cropping systems generated considerable interest, and follow-up meetings have been scheduled with several environmental advocacy groups to discuss next steps.

Following the completion of the project, the fact sheet created for this project and link to LCCMR and the final report will be shared via Science Museum social media platforms.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 08d Agricultural Weed Control Using Autonomous Mowers - $750,000 TF

Eric Buchanan
U of MN - Morris
46352 State Hwy 329
Morris, MN 56267

Phone: (612) 624-8869
Email: buch0123@morris.umn.edu
Web: http://www.umn.edu

Appropriation Language
$750,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the West Central Research and Outreach Center at Morris to design, integrate, and field-test new technology mowers to control weeds, reduce herbicide use, reduce energy costs, and improve native vegetation and forage quality on agricultural lands. This appropriation is subject to Minnesota Statutes, section 116P.10. 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
An autonomous electric mower, along with a solar powered charging trailer, was successfully developed and demonstrated to control weeds in cow pastures. The “Cowbot” eliminates the need for pesticides in conventional pastures and provides a carbon-free solution for organic pastures.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesota farmers and land managers are engaged in an annual battle to control weeds. Each year, significant amounts of herbicide, diesel fuel, labor, and money are expended to stay ahead of weed infestations. Our project team developed an autonomous mowing robot, we call Cowbot, that can design a path to mow a pasture given the GPS coordinates of the pasture corners. The Cowbot can then accurately follow this path and return to its starting point when mowing is completed. A specially designed solar charging trailer is placed at the starting point to recharge the Cowbot when its batteries are low. Widespread adoption of the technology we demonstrated could lead to:

- Significant reductions in the use of herbicides on agricultural and natural lands,
- Replacement of fossil fuel with clean energy produced locally,
- Protection of water resources by preventing surface and ground water contamination with herbicides,
- Reducing the impact of herbicide on wildlife, desired native plant species, and the evolution of herbicide tolerant ‘super’ weeds.

The project team consisted of researchers at the University of Minnesota from several departments working together to develop a robotic pasture mower in partnership with a Minnesota manufacturing company, The Toro Company. Safety protocols were developed for field testing and safety implications of autonomous farm vehicles in general were researched. The Cowbot was field tested in pastures at the U of MN West Central Research and Outreach Center (WCROC) comparing its performance to a conventional mower deck pulled by a diesel tractor. The Cowbot successfully mowed three, two-acre pasture paddocks demonstrating three different path strategies. It returned to the charging trailer after

mowing each paddock and was successfully recharged. A dairy producer reviewed the mowed pasture and judged the Cowbot mowed paddocks to offer equivalent or better control of weeds than the tractor mowed paddocks.

PROJECT RESULTS USE AND DISSEMINATION
Several academic papers were published relating to technology used to design mowing paths and control the Cowbot. The Cowbot was demonstrated to farmers and land managers at several events like the Midwest Farm Energy Conference at the WCROC in 2019 and 2022. It was also featured in an episode of the PBS television show "The Prairie Sportsman" along with interviews with several project team members airing in March 2021. The Cowbot was a featured live demonstration at a state-wide expo in August 2021 called FarmFest. Finally, the Cowbot appeared in several print media articles including the Star Tribune and AgWeek.

Project Completed: 6/30/2022
FINAL REPORT
Cowbot: System Design and Field Evaluation of an Autonomous Weed Mowing Robot for Cow Pastures - 7 pgs

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Subd. 08f Develop Strategies for Timber Harvest to Minimize Soil Impacts to Maintain Healthy and Diverse Forests - Research Project - $200,000 TF

Charlie Blinn
U of MN
1530 Cleveland Ave N
St. Paul, MN 55108

Phone: (612) 624-3788
Email: cblinn@umn.edu
Web: https://www.forestry.umn.edu

Appropriation Language
$200,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop strategies and practical tools to minimize soil compaction and other impacts across a range of conditions during timber harvest to maintain timber availability, improve regeneration of diverse forests, and benefit wildlife habitat. 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
Reduced snowfall predicted with climate change is likely to increase the amount of soil frost during winter, increasing the times when forest harvesting can safely occur. We developed tools that will allow managers to predict when and where optimal soil conditions occur to minimize impacts of forest harvesting.

OVERALL PROJECT OUTCOME AND RESULTS
Soils and forest health can be impacted during forest harvesting depending on how much frost is present during winter and how wet the soils are in summer. Climate change is expected to change these

conditions, creating challenges for managers to determine when the optimal harvest time will occur. Our objectives were to determine how 1) snow cover influences the rate of frost development; 2) soil moisture influences soil strength; and 3) each of those relationships vary across areas that span a range of soil drainage (relative wetness). We conducted snow removal and rainfall reduction treatments in three aspen forests and monitored soil temperature and moisture, frost development, and soil strength for a period of three years. Treatments were conducted across a range of drainage classes that were expected to influence the treatment response and which could be readily identified by managers in the field (to improve application of any findings). We determined that snow removal causes significant increases in frost development and that the relationship is dependent on relative soil wetness of the forest: wetter, more poorly drained soils had lower frost development compared to drier, well-drained soils. Rainfall reduction had limited and inconsistent effects on soil moisture, possibly because of the small plot size. The relationships between soil moisture and soil strength were also inconsistent, hindering identification of the optimal soil moisture content where soil strength is optimal to reduce harvest impacts under non-frozen conditions. Based on our findings and previously developed metrics, we developed a map of harvest suitability for all forested areas in Minnesota under two scenarios, which can be used by managers and landowners to identify the season when forest harvesting is likely to have the smallest impact on soil and forest health. The results provide managers with tools that support sustainable forest management and the benefits it provides.

PROJECT RESULTS USE AND DISSEMINATION

We summarized the primary project findings into peer-reviewed journal articles that highlight key relationships and considerations that managers can use when determining the optimal time to conduct forest harvests. The information was also shared with resource managers at the annual Research Review conducted annually by UMN's Sustainable Forestry Education Cooperative. The journal articles are still in publication, but a graduate student thesis is available here that outlines the primary findings. In addition, we created a map of harvest suitability by season for the forested region of Minnesota that can be accessed here. These two references are missing their hyperlink info.

Project Completed: 6/30/2022

FINAL REPORT

The effects of combined throughfall reduction and snow removal on soil physical properties across a drainage gradient in aspen forests of northern Minnesota, USA - 10 pgs

Limited Effects of Precipitation Manipulation on Soil Respiration and Inorganic N Concentrations across Soil Drainage Classes in Northern Minnesota Aspen Forests - 15 pgs

The effects of combined throughfall reduction and snow removal on soil physical properties across a drainage gradient in aspen forests of northern Minnesota, USA - 47 pgs

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Subd. 08g Restoring Wetland Invertebrates to Revive Wildlife Habitat - Research Project - $400,000 TF

Megan Fitzpatrick
MN DNR
102 23rd Street NE
Bemidji, MN 56601

Phone: (507) 308-2284
Email: megan.fitzpatrick@state.mn.us

Appropriation Language
$400,000 the second year is from the trust fund to the commissioner of natural resources to assess invertebrate amphipods in wetlands and explore stocking them as a valuable food source for ducks and other wildlife in the Prairie Pothole Region of the state. 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
Our research showed amphipods are particularly sensitive to their wetland environments. High abundances of amphipods useful as wildlife food requires wetlands with high plant diversity and abundance, low concentrations of pesticides, and few fishes. Our work suggests many ways to manage and protect amphipod populations and their high biodiversity habitats.

OVERALL PROJECT OUTCOME AND RESULTS
Amphipods (shrimp-like aquatic invertebrates) are found in a variety of Minnesota's wetlands and are important food for many species of waterfowl, amphipods, and fish. Two species of prairie amphipods (Gammarus lacustris and Hyalella azteca) have declined in recent decades and have been linked to decline in the continental population of Lesser Scaup (Aythya affinis) ducks. Our project had two objectives: (1) to learn what wetland conditions support high abundances of amphipods, and (2) to assess whether "stocking" amphipods in seemingly high-quality wetlands was successful at establishing new populations.

We surveyed 66 wetlands across western Minnesota for amphipod abundance, fish, aquatic plants, water quality, and surrounding landcover. Key findings included a positive relationship between amphipod abundance and aquatic plant biodiversity, and negative relationships to pyrethroid pesticide levels and several fish species, especially black bullheads (Ameiurus melas).

We also collected G. lacustris amphipods and stocked them into wetlands at 19 sites. We surveyed amphipods before and up to 3 years after stocking to assess survival and reproduction. G. lacustris were detected in only one stocked site after stocking, suggesting that our stocking methods did not create sustained new populations.

Our results will inform management actions to support wetland quality and wildlife populations of interest to Minnesota's waterfowl hunters, birdwatchers, and other wetland enthusiasts. Our results suggest amphipods will benefit from actions that increase aquatic plant diversity, remove and prevent black bullhead and other fish invasions, and reduce impacts of high intensity agriculture. Management might include drawdowns, fish barriers, upland riparian buffers, and reduced agricultural pesticide use. Further, results from Objective 1 can be used to better target stocking wetlands where G. lacustris are likely to thrive and spread on the Minnesota landscape. We are sharing results with natural resource managers and the public via publications, presentations, and depositing data in publicly-accessible repositories.

PROJECT RESULTS USE AND DISSEMINATION
We trained, mentored, and provided paid work experience to two successful master's students and 23 undergraduates, producing two theses and five capstone projects. We shared information via MNDNR Research Summaries, two open-access scientific publications describing invertebrate sampling methods and amphipod-aquatic plant relationships, and 16 oral and poster presentations at professional conferences (see YouTube and ResearchGate). We have drafted a third paper and planned four more.

Additional outreach included a MNDNR virtual presentation, Minnesota Conservation Volunteer article, Minnesota Public Radio podcast and article, KSTP-TV broadcast, and informal communication with curious members of the public in the field, site managers, and landowners.

Project Completed: 6/30/2022
FINAL REPORT
High abundance of a single taxon (amphipods) predicts aquatic macrophyte biodiversity in prairie - 21 pgs
High abundance of a single taxon (amphipods) predicts aquatic macrophyte biodiversity in prairie wetlands - 21 pgs
Protocols for Collecting and Processing Macroinvertebrates from the Benthos and Water Column in Depressional Wetlands - 32 pgs

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Subd. 08h Preserving Minnesota's Native Orchids - Phase 2 - $259,000 TF

David Remucal
U of MN - Landscape Arboretum
3675 Arboretum Dr
Chaska, MN 55318

Phone: (952) 443-1418
Email: remu0005@umn.edu
Web: www.arboretum.umn.edu

Appropriation Language
$259,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Minnesota Landscape Arboretum to expand collection and preservation efforts to enable long-term conservation of at least 25 of the 48 native orchid species in Minnesota and to continue propagation and cultivation research. 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
Native orchid populations across the state have been stored in a long-term seedbank at the Minnesota Landscape Arboretum, preserving these native jewels. This project also preserved many of the fungal partners that orchids need to survive and establish in the wild.

OVERALL PROJECT OUTCOME AND RESULTS
This project worked to bank the seed of more of Minnesota's native orchid species, a complex and difficult plant family to conserve because of their complex biology. As part of this seed banking effort, there is a wealth of research that must be done with each species, to determine how best to store seed and propagate them and what the soil fungal partners are and how those fungi can be used to establish these notoriously difficult species, either in display beds for visitors to enjoy or in the wild to establish, augment or protect their presence in or landscapes. There are about 46 native orchid species in Minnesota and understanding how to propagate them and store their seed had not previously been well-established for nearly all of them. This project sought to develop that information for as many of those species as possible. Overwhelmingly successful, multiple populations of these plants were banked for nearly all species and research on nearly all 46 species has been successful and continues. A fungal

bank of nearly 500 specimens was also established to grow and work with the fungal partners that orchids need.

This work will not only benefit visitors to the Arboretum, it is already being used by groups across the state, region and country for a variety of projects that would have previously been unthinkable or unsuccessful, including outplantings of native orchids in restored or protected landscapes and transplants and rescues of plants under immediate threat from development or construction. The resulting information we have produced, and continue to produce, is invaluable for any groups wanting to work with these species.

PROJECT RESULTS USE AND DISSEMINATION
Orchids brought into the seedbank and propagated at UMLA have been displayed in existing and new display beds with a series of educational brochures. Displaying orchids at UMLA allows visitors to see many species that they would likely never see in person otherwise. We give talks, in person or virtually, and have been able to reach out in a variety of media formats, including a website. Finally, we have been able to use the techniques, infrastructure and expertise developed during this project to assist a variety of groups in a variety of conservation-aimed projects related to native orchids.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 09 Land Acquisition, Habitat, and Recreation

Subd. 09a Grants for Local Parks, Trails, and Natural Areas - $2,000,000 TF

Audrey Mularie
MN DNR
500 Lafayette Rd
St. Paul, MN 55155

Phone: (651) 259-5549
Email: audrey.mularie@state.mn.us
Web: https://www.mndnr.gov

Appropriation Language
$2,000,000 the second year is from the trust fund to the commissioner of natural resources to solicit, rank, and fund competitive matching grants for local parks, trail connections, and natural and scenic areas under Minnesota Statutes, section 85.019. The appropriation is for local nature-based recreation and connections to regional and state natural areas and recreation facilities and does not include athletic facilities such as sport fields, courts, and playgrounds. 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
Provide approximately 14 matching grants to local units of government for local parks, acquisition of locally significant natural areas and trails to connect people safety to desirable community locations and

regional or state facilities. Park development includes nature-based recreation facilities and does not include playgrounds, sports courts or sport fields.

OVERALL PROJECT OUTCOME AND RESULTS
The primary project results include,

- Six Outdoor Recreation grants to provide nature based outdoor recreation opportunities including park trails, natural resource interpretive opportunities, boating and fishing facilities in Andover, Brooklyn Park, Princeton, St. Peter, Wright County and Zumbrota.
- Four Natural and Scenic Area grants to help protect 139.5 acres of significant natural and scenic areas in Bayport, Wright and Washington Counties through fee title and permanent conservation easement.
- Four Local Trail Connection grants to provide safe, accessible trails to parks, schools, and other significant locations within the communities of Austin, Canby, Luverne and Moose Lake.
- Project administration for the grants was completed for $50,000. Two application cycles were completed, applications reviewed and selected for grants. Active projects were monitored, financial review completed, grantees reimbursed, final site visits completed as needed, projects close, land acquisition report filed.

The Outdoor Recreation (Local Parks), Natural and Scenic Area and Local Trail Connections Grant Programs provide competitive matching grants for local parks, natural areas and trails to local governments for land acquisition and improvements related to parks and trails. Many projects include renovation of existing facilities to improve safety and accessibility, acquisition of locally significant natural and scenic areas, completion of trail linkages to safely connect where people live to desirable locations within the community and/or connecting local trails to regional or state facilities.

PROJECT RESULTS USE AND DISSEMINATION
A Request for Proposal is announced for the programs in December of each year through our park and trail contacts e-mail list and regional and statewide organization. Regional and statewide organizations are encouraged to forward to their members. Program information and applications are available to download on the DNR Recreation Grants webpage under each specific program. A list of the awarded projects is posted on the program webpages under recent grants.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 09b Develop Mesabi Trail Segment From County Road 88 to Ely - $600,000 TF

Bob Manzoline
St. Louis & Lake Counties Regional Railroad Authority
111 Station Rd
Eveleth, MN 55734

Phone: (218) 744-2653
Email: bmanzoline@rrauth.com

Appropriation Language
$600,000 the second 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 environmental assessment, permitting, right-of-way easements or other acquisition as needed, engineering, and construction of an approximately three-mile-long bituminous surface section of the Mesabi Trail between Ely and the intersection of Highway 169 and County Road 88. 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
The Mesabi Trail is a project to build a paved trail from Grand Rapids to Ely. At the conclusion of this phase of the project, approximately 150 miles of the trail are complete. With this appropriation, permitting and engineering was completed, and construction began for this segment of the trail from County Road 88 to the City of Ely.

OVERALL PROJECT OUTCOME AND RESULTS
The funds for this project have been spent toward the development of Mesabi Trail segment from County Road 88 to Ely. Engineering design, specifications, environmental and permitting have all been completed. Construction has started. We will now use the funds from our M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 09b – Mesabi Trail: CSAH 88 to Ely ($1,650,000) to complete the Construction Engineering Management and Construction for this 3.0 mile trail segment.

PROJECT RESULTS USE AND DISSEMINATION
The Mesabi Trail news and updates are provided through a variety of media, marketing and publications. Web site is: Mesabitrail.com. The following are some of the groups & organizations that disseminate Mesabi Trail information and typically include updates of newly completed trail segments and activities:

- Club Mesabi (10,000 maps & web site)
- Iron Range Tourism (30,000 brochures & web site)
- MN Office of Tourism
- amperes radio
- Parks & Trails, Home & Away, other private magazines
- Over 240,000 trail users per year
- Great River Energy/Mesabi Trail annual tour
- Named by the Star Tribune as "Best of Minnesota" in year 2013
- Named by Bicycle Magazine as "top 10 in the country"
- Information distributed at over 70 locations including Chambers of Commerce, visitor centers, businesses
- MN DOT/Pedal MN bikeways map
- "Second best trail in Midwest USA" Dubuque Iowa, 2017

ENRTF Acknowledgement is provided in these dissemination activities per the Acknowledgement Requirements.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 09d Mississippi Blufflands State Trail - Red Wing Barn Bluff to Colvill Park Segment - $550,000 TF

Jay Owens
City of Red Wing
315 Fourth St W
Red Wing, MN 55066

Phone: (651) 385-3625
Email: jay.owens@ci.red-wing.mn.us
Web: http://www.red-wing.org

Appropriation Language
$550,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the city of Red Wing to be used with other funds to construct an approximate three-quarter-mile-long hard-surfaced segment of the Mississippi Blufflands State Trail along Red Wing's Mississippi River riverfront from Barn Bluff Regional Park to Colvill Park. 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 was intended to enhance Minnesotans experience of the natural beauty of the state through the development of 0.75 miles of trail. While much design and planning were completed for this trail, the actual trail could not be built due to land acquisition problems.

OVERALL PROJECT OUTCOME AND RESULTS
This project proposed to construct an approximate a 0.75-mile-long segment of the Mississippi Blufflands State Trail along Red Wing's riverfront from Barn Bluff Regional Park to Colvill Park. A portion of the trail required the purchase of fee interest of a right-of-way held by the Canadian Pacific Railway. Early in the project, the City of Red Wing achieved agreement with the CP Railway to acquire this ROW, and trail planning was underway. Unfortunately, during the project period, CP Railway's director of real estate abruptly left. This, followed by the COVID epidemic, essentially stalled acquisition negotiations. While the project was granted a one-year COVID extension through the legislature, the railway continued to be non-responsive until after the grant expired.

Over the late spring and early summer of 2022, the Canadian Pacific Railway has been responsive to our need to the fee interest in the railroad ROW necessary to build the project. The ENRTF appropriation ended on June 30, 2022. In July the CP Railway agreed to sell the needed ROW. The CP Railway amount needed was identified as approximately 25,473 square feet with approximately 5,248 square feet identified for temporary construction easement needs. CP Railway staff agreed to maintain the price of $3.55 per square foot to acquire right of way necessary for the project, approximately 25,475 square feet or $90,429.15, using non-ENRTF funds. No other costs will be associated with the agreement.

On Monday, August 22, 2022, the purchase agreement was approved and executed by the City Council. Although this process took multiple years and required the return of grant funding the city remains committed to seeking full funding for this important Mississippi riverfront trail segment.

We expect the closing for the property to be completed within 90 days.

PROJECT RESULTS USE AND DISSEMINATION
While desired results of this project—0.75 miles of trail built—were not ultimately completed during this appropriation period, the City of Red Wing diligently updated the city council as to progress of this trail, including tours of the proposed trail route. The city also provided press releases regarding ENRTF funding. At the City Council meeting of August 22, 2022, it was stated during the project period no progress was gained on the property acquisition and the ENRTF grant had expired. The project is at 65% design with level three cost estimates completed.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 09e Swedish Immigrant Regional Trail Segment within Interstate State Park - $2,254,000 TF

Joseph Tart
Chisago County
313 N Main St, Suite 240
Center City, MN 55012

Phone: (651) 213-8960
Email: joseph.tart@chisagocounty.us

Appropriation Language
$2,254,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Chisago County Environmental Services to construct an approximate one-half-mile regional county trail segment within Interstate State Park from the end point of the existing trail at the park boundary to city hall including a trail bridge over the ravine and parking and trailhead improvements and to conduct a natural and cultural review to determine the feasibility and route of a future section of the trail through the park. 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 Swedish Immigrant Regional Trail within Interstate Park was designed and constructed to protect the natural resources within the State Park Land while preserving rare plants, native tree species and wetlands. The Interstate State Park trail enhances Minnesota's air, water, and wildlife by avoidance and mitigation of many natural resources that were present. Resulting trail is a 10 ft. wide bituminous surface with a 160 ft. long bridge crossing a ravine.

OVERALL PROJECT OUTCOME AND RESULTS
The Swedish Immigrant Regional Trail project was constructed within Interstate Park State Park and into the City of Taylors Falls. This segment of trail has a ten-foot-wide bituminous trail surface and is approximately .60 miles in length that was designed as an ADA compliant multi-use and non-motorized trail. The main goal of this project was to expand the Swedish Immigrant Regional Trail further east to allow a safe route for pedestrians and bicyclist to travel. The project will benefit many local communities and Minnesotans alike by connecting multiple cities along this trail corridor. The trail will likely attract new visitors each year to enjoy the majestic views of Interstate State Park while also providing health

and wellness benefits.

The overall project was implemented years prior to construction through the vision and involvement of many organizations, stakeholders, cities and residents to construct a County Regional Trail within a State Park and along a historic rail corridor to Taylors Falls. During the construction phase many accomplishments were achieved by excellent planning and cooperation, some of these included a beautiful 160 ft. bridge over a ravine and a trailhead that incorporated many great landscaping features that are prevalent in the region. Throughout the entire construction project one of the main challenges was to find the perfect trail alignment that meet all necessary trail compliances while also minimized impacts to many of the Interstate State Park environmental, natural, and cultural resources.

PROJECT RESULTS USE AND DISSEMINATION
The Minnesota Environmental and Natural Resources Trust Fund (ENRTF) acknowledgement has be very prevalent throughout the entire project. The use of the trust fund logo and attributed language have been printed in newspaper publications and Environmental Services Newsletters, social media platforms and signage along the Swedish Immigrant Regional Trail corridor. Throughout the project we have created several documents and other online resources to help communicate and receive public outreach. Some of these include the use of electronic public surveys and mailing for community input and involvement.

Project Completed: 6/30/2021
FINAL REPORT

Subd. 09g Protecting Mississippi River Headwaters Lands through Local, State, and Federal Partnership - $700,000 TF

Josh Doty
City of Baxter
13190 Memorywood Dr
Baxter, MN 56425

Phone: (218) 454-5111
Email: jdoty@baxtermn.gov
Web: http://www.baxtermn.gov/

Appropriation Language
$700,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the city of Baxter, in cooperation with Brainerd Public Schools and the Camp Ripley Sentinel Landscape Program, to acquire about 200 acres of forested land on the upper Mississippi River adjacent to Mississippi River Overlook Park for multiple public benefits, including being an outdoor classroom for local schools. To be eligible for reimbursement, costs for real estate transactions must be specific to this acquisition and documented as required in subdivision 15, paragraph (k).

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The project preserved 200 acres of forest on the upper Mississippi River. After the grant was awarded, the project grew to ultimately preserve 1,338.4-acres locally. Of this total, Baxter now has 880-

contiguous acres (including the project 200 acres) of high-quality natural resource property preserved within Baxter.

OVERALL PROJECT OUTCOME AND RESULTS

The 200-acres targeted for this protection project were at risk of being sold for development along the city limits of Baxter and the scenic rolling hills of the Mississippi River. Another downfall of development of the land beyond the conservation impacts are the encroachment that hinders training of soldiers at Camp Ripley. Camp Ripley has prioritized protecting lands near the military base to continue their important training mission without negatively impacting citizens near the base. The major project objective was to purchase and permanently protect the 200-acres that are directly adjacent to Baxter Overlook Park to the west. This land would also become part of Forestview Middle School's outdoor classroom.

After discussions with Potlatch, as well as Sylvan Township, Cass County, and Crow Wing County, it became apparent that this project could utilize more funding and have broader local government support and protect more forestland in a larger context. This Baxter Overlook Park project appraised less than anticipated at the project outset, and utilized $400,000 in Department of Defense funding, and $330,322 in LCCMR funding for a total cost of $730,322 (55% DoD funding; 45% LCCMR funding). Additional non-federal funding was needed for match in the larger project, and the increased LCCMR match allowed for $2.1 million in DoD funding and $1.29 million in LSOHC to be applied over the entire project scope of 1,546.84-acres.

This protection project will grant Minnesotans the ability to recreate, hunt, and enjoy the public lands that encompass the entire project area, even beyond the City of Baxter. It will also allow for hundreds of middle school students to learn about Minnesota's forests each year, and perhaps inspire future generations to cherish and continue to protect our shared natural resources.

The project was completed, and the property was purchased by the City of Baxter on June 30, 2020. Along with this 198.5-acre Baxter Overlook Park addition, TCF, Baxter, and Camp Ripley partners were also able to protect 1,338.4-acres of additional forestlands from Potlatch in this area in this same negotiation to also be permanently protected utilizing LSOHC and Department of Defense funding, totaling more than $3,700,000. Multiple public partners, including Baxter, Cass County, Crow Wing County, and Sylvan Township now hold those properties for public use and wildlife habitat benefits. The scope of the project grew over time and achieved a greater outcome than the partners anticipated in 2018. Additional non-federal funding was needed for match in the larger project, and the additional LCCMR match allowed for $2.1 million in DoD funding to be applied over the entire project scope.

PROJECT RESULTS USE AND DISSEMINATION

The City notified the public of the environmental, educational, open-space recreational opportunities of the property with an article in the local Baxter newsletter, which is sent to all residents. City staff also joined Camp Ripley Environmental staff, and The Conservation Fund staff by going on-air on WJJY radio to discuss the environmental project and opportunities. Lastly, on November 2, 2021, the City Council authorized City staff to execute a contract with SRF Consulting to guide the City through an Open Space Master Plan study. A significant portion of the study is public outreach and civic engagement to help the City develop an open space master plan for the property.

Pieces about this project were published in MinnPost, the Brainerd Dispatch, and the Conservation Fund website and a Conservation Fund press release.

Project Completed: 6/30/2020
FINAL REPORT

Subd. 09k Minnesota State Parks and State Trails - $2,500,000 TF

Shelby Kok
MN DNR
500 Lafayette Rd
St. Paul, MN 55155

Phone: (651) 259-5590
Email: Shelby.Kok@state.mn.us
Web: https://www.dnr.state.mn.us/

Appropriation Language
$2,500,000 the second year is from the trust fund to the commissioner of natural resources to acquire about 163 acres of high-priority in holdings from willing sellers within the legislatively authorized boundaries of state parks and trails in order to protect Minnesota's natural heritage, enhance outdoor recreational opportunities, and improve the efficiency of public land management. Priorities include but are not limited to Tettegouche, Sibley, and Minneopa State Parks and the Goodhue Pioneer State Trail. A list of proposed acquisitions is required in the work plan. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

Project Completed: 6/30/2022
FINAL REPORT

Subd. 10 Emerging Issues Account

Sub-Project 01: State-wide Reconnaissance of SARS-CoV-2 in Drinking Water Supplies - $59,297 TF

Tim LaPara
U of M
500 Pillsbury Dr SE
Minneapolis, MN 55455

Phone: (612) 624-6028
Email: lapar001@umn.edu
Web: http://www.cege.umn.edu/directory/faculty-directory/lapara.html

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
There were concerns that SARS-CoV-2, the virus that causes COVID-19, could contaminate drinking water supplies. In this study, we investigated 30 drinking water samples from homes around the State of

Minnesota supplied by either a private well or a public water system, testing for SARS-CoV-2. To date, we have not been able to detect SARS-CoV-2 in any Minnesota drinking water samples.

OVERALL PROJECT OUTCOME AND RESULTS

Soon after the COVID-19 pandemic began, it was observed that the SARS-CoV-2 was detectable in the feces of infected individuals and thus was likely to be present in raw sewage. With this knowledge, researchers developed techniques to monitor the extent of COVID-19 spread in communities by quantifying the virus in untreated municipal wastewater. Given the presence of this virus in raw sewage, concerns were expressed that it could contaminate our public and private drinking water supplies, either from leaky sewer pipes, municipal wastewater effluent, or septic systems. Although well-functioning public water and wastewater facilities are typically very good at preventing the spread of disease via the fecal-to-oral route, this project was undertaken to confirm that SARS-CoV-2 was not contaminating our drinking water. Because SARS-CoV-2 is a pathogen that infects the lungs, the risk of exposure from water supplies is via inhalation of water droplets while showering or other uses. We therefore used filters to collect the microorganisms from 30 high-volume drinking water samples (sample volume: 500-1000 liters) from various locations within the State of Minnesota. These samples were obtained from homes supplied by private wells that do not employ any treatment as well as from homes supplied by public water systems that treat the water, including but not necessarily limited to, disinfection with chlorine. We were unable to detect SARS-CoV-2 in any of these samples; positive-control sewage samples collected from a municipal wastewater treatment plant, however, confirmed that our assays were working and could detect SARS-CoV-2 in water samples. Our results, therefore, provided evidence to suggest that, at the time of our study in the spring and summer of 2020, SARS-CoV-2 was not present in our public and private water supplies and that drinking water was not a likely route of exposure to SARS-CoV-2.

PROJECT RESULTS USE AND DISSEMINATION

We have shared our results with LCCMR staff and with Kirsti Marohn from Minnesota Public Radio (MPR) and Greg Stanley from the Minneapolis Star Tribune. We also presented our research results at the annual meeting of the Minnesota section of the American Water Works Association (September 24, 2020) and during an online seminar hosted by the Minnesota Pollution Control Agency (December 9, 2020).

Subproject 01 Completed: 06/30/2021
FINAL REPORT

Sub-Project 03: Environmental Assessment of CWD Prions at the Beltrami County Deer Carcass Dump Site - $108,232 TF

Peter Larsen
U of MN - College of Veterinary Medicine
1971 Commonwealth Avenue
St. Paul, MN 55108

Phone: (612) 626-1694
Email: plarsen@umn.edu

Web: https://vetmed.umn.edu/bio/college-of-veterinary-medicine/peter-larsen

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

We confirmed CWD-positive deer remains within the dumpsite and that the positive remains came from the neighboring cervid farm. We recommend: 5 years of CWD surveillance in the region, monitoring water runoff, routine CWD-testing of deceased cervid-farm fawns, monitoring wild mammal health in the area due to documented CWD risks.

OVERALL PROJECT OUTCOME AND RESULTS

In April 2021 we were notified by the DNR that deer carcasses from a CWD positive deer-farm in Beltrami County had been dumped on public land and were asked to help with CWD-testing of the remains. Our initial tests confirmed some remains were CWD positive. CWD-prions remain infectious within the environment for years. Therefore, the goals of our project were to complete testing of deer remains, collect samples of soil, water, and plants for future testing, and perform a CWD-prion risk assessment. We used RT-QuIC testing to identify CWD-prions in biological and ecological samples, and we performed DNA analyses to see if the dump-site carcasses came from the neighboring cervid farm. We collected deer remains, soil, plant, fungi, and water samples from the ~12-acre site. At least 11 deer were deposited, with carcasses subsequently pulled apart by scavengers. Forty-four locations had white-tailed deer remains and 58 carcass samples were suitable for RT-QuIC testing. Of these, 14 were statistically positive for CWD. Fly larvae and soil associated with the positive remains also tested positive for CWD. DNA analyses confirmed positive remains originated from the neighboring cervid farm. Based on our findings we recommend the state: conduct a total of 5 years of CWD surveillance in the region, perform routine testing of deceased fawns in cervid farms, and support research monitoring wildlife health in the region (e.g., recent data show raccoons and voles are susceptible to CWD-prions). Our team will continue monitoring water runoff from the site, as well as soil, plants, and fungi to help monitor CWD-prion contamination in the region. Our recommendations are based on the latest CWD science and will improve CWD monitoring of both wild and captive deer in Minnesota. Our research will ultimately help Minnesotans better understand the environmental risk of CWD prion contamination throughout the state.

PROJECT RESULTS USE AND DISSEMINATION

We presented a poster describing the biological sample-collection and assessment at the dumpsite during the 70th Annual International Conference of the Wildlife Disease Association in Madison, WI. A manuscript was published reporting results of our engagement with Tribal Nations in the region (available here) and a second paper reporting our research findings is to be submitted to a peer-reviewed journal in October 2022. Updates of the project have been made to the MN Legislature, three public information meetings, the MN Board of Animal Health work conference, and two University of Minnesota events. Additional updates will be provided to our state and tribal nation partners and at MNPRO outreach events in 2023 as well as on the MNPRO website.

Subproject 03 Completed: 06/30/2022

FINAL REPORT