III. Completed Research Projects

"a summary of any research project completed in the preceding biennium;"

The following documents include:

- Summaries of accomplishments for each appropriation year and short abstracts for all projects completed since the previous biennial report of January 15, 2019. Research projects have been marked as such in the description.
- Spreadsheet of all research projects completed between January 1, 2019 and December 31, 2020.

Additional information:

- The abstracts describe the general accomplishments of each completed project and are current as of 12/31/2020. See http://www.lccmr.leg.mn for additional project information, including Final Reports.
- 138 projects were completed with a total of $65,725,832.
- Legal citations for completed projects:
  1. M.L. 2019, First Special Session, Chapter 4, Article, 2, Section 2
  2. M.L. 2018, Chapter 214, Article 4, Section 2
  3. M.L. 2017, Chapter 96, Section 2
  4. M.L. 2016, Chapter 186, Section 2
  5. M.L. 2015, Chapter 76, Section 2
  6. M.L. 2014, Chapter 226, Section 2
  7. M.L. 2013, Chapter 52, Section 2

1. **M.L. 2019 Projects Completed**
   January 15, 2019 – January 15, 2021

   MN Laws 2019, First Special Session, Chapter 4, Article 2, Section 2

M.L. 2019 Projects

MN Laws 2019, First Special Session, Chapter 4, Article 4 Section 2 (beginning July 1, 2015)

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

Subd. 03 Foundational Natural Resource Data and Information

Improving Statewide GIS Data by Restoring the Public Land Survey

Subd. 03m $135,000 TF (FY2020)

Patrick Veraguth
Minnesota Association of County Surveyors
526 Willow Drive, PO Box 398
Alexandria, MN 56308
Phone: (320) 762-2964
Email: patv@co.douglas.mn.us
Web: http://macsinfo.org/

Appropriation Language
$135,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Minnesota Association of County Surveyors to conduct a pilot project with Grant County to remonument and certify the public land survey corners in Lawrence Township. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

Project due to be completed: 12/30/2020 **Work Plan**

Managed Aquifer Recharge

Subd. 04t $150,000 TF (FY2020)

John Bilotta
U of MN - Water Resources Center
173 McNeal Hall
1985 Buford Avenue
St. Paul, MN 55108
Phone: (612) 624-7708
Email: bilot002@umn.edu
Web: https://www.wrc.umn.edu/

Appropriation Language
$350,000 the first year is to the Board of Regents of the University of Minnesota, Water Resources Center, for a comprehensive study of the economic benefits of managed aquifer recharge and to make recommendations to enhance and replenish Minnesota's groundwater resources. The study must include, but is not limited to:

(1) examining the potential benefits of enhancing groundwater recharge in water-stressed areas;
(2) assessing the relationship to changing seasonality and intensity of precipitation on groundwater recharge rates;
(3) reviewing the approaches to manage recharge in geologically appropriate areas;
(4) identifying policy options, costs, and barriers to recharging groundwater; and

(5) assessing the economic returns of options for groundwater recharge.

In conducting the study, the Water Resources Center must convene a stakeholder group and provide for public participation.

Project due to be completed: 12/30/2020 **Work Plan**

Britton Peak to Lutsen Mountain Bike Trail

Subd. 09i $350,000 TF (FY2020)

Tim Kennedy
Superior Cycling Association
PO Box 1032
Grand Marais, MN 55604
Phone: (218) 370-0955
Email: tkennedy@boreal.org
Web: https://superiorcycling.org/

Appropriation Language
$350,000 the first year are from the trust fund to the commissioner of natural resources for an agreement with the Superior Cycling Association to create a sustainably designed single-track mountain bike trail connecting trail clusters and trailheads between Britton Peak in Tofte and Lutsen Mountains as part of northeast Minnesota's effort to become a national recreation destination. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Recreation demands for mountain biking in Minnesota, especially Northeastern Minnesota, have grown to require more sustainably designed and purpose built mountain bike trails. The Cook County Mountain Bike System masterplan prepared for the Superior Cycling Association by the Arrowhead Regional Development Commission calls for development of clusters of mountain bike trails at Britton Peak in Tofte, Pincushion Mountain in Grand Marais and Lutsen Mountains in Lutsen with a connector trail between these three clusters. This project completed the Jackpot and High Climber trails between the existing trail clusters at Britton Peak and Lutsen Mountains, approximately 16 miles. The Superior Cycling Association in partnership with the US Forest Service and Cook County built these mountain bike trails to the highest sustainable trail design standards to minimize environmental impacts while utilizing the relief and geologic features found along the North Shore.

This project is part of a growing number of destination mountain bike trails to be found in Northeast Minnesota, including the City of Duluth, Cuyuna in Crosby, Giant's Ridge, Redhead in Chisholm, Toiga in Cohasset, and more in the works. Recreation trails are a driving force to bring visitors to these areas of the state and make significant impacts on the local economy.

PROJECT RESULTS USE AND DISSEMINATION

Unfortunately, due to COVID-19, this trail was opened for use unceremoniously with no major announcements or Grand Opening celebration. However, riders did hear about the trail on the Superior Cycling Association, Visit Cook County, and other website as well as on trail aps that riders use. Response from riders echoed a similar sentiment, "this is the best trail in the State…I'll be back".

When COVID restrictions are over and large gatherings are again allowed, the Superior Cycling Association will be holding a Grand Opening which will invite riders, media, partners, and local businesses to celebrate this mountain bike trail resource.

Project Completed: 12/30/2020 **FINAL REPORT**

Crane Lake to Vermilion Falls Trail

Subd. 09n $400,000 TF (FY2020)

Bruce Beste
Voyageur Country ATV
Box 414
Crane Lake, MN 55725
Phone: (218) 391-5108
Email: voyageurcountryatv@gmail.com
Web: www.VoyageurCountryATV.com

Appropriation Language
$400,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with St. Louis County in cooperation with Voyageur Country ATV Club to designate and improve a wooded trail from Crane Lake to Vermilion Falls to accommodate all-terrain vehicle and snowmobile users. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

Project due to be completed: 10/30/2020 **Work Plan**

1. **M.L. 2018 Projects Completed**
   January 15, 2019 – January 15, 2021

   MN Laws 2018, Chapter 214, Article 4, Section 2

M.L. 2018 Projects

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

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

Subd. 03 Foundational Natural Resource Data and Information

County Geologic Atlases - Part A

Subd. 03a $1,240,000 TF

Dale Setterholm
U of MN - MN Geological Survey
2609 Territorial Rd
St. Paul, MN 55114
Phone: (612) 626-5119
Email: sette001@umn.edu
Web: http://www.mngs.umn.edu

Appropriation Language
$1,240,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota, Minnesota Geological Survey, to continue producing county geologic atlases for the purpose of informed management of surface water and groundwater resources. This appropriation is to complete part A, which focuses on the properties and distribution of earth materials to define aquifer boundaries and the connection of aquifers to the land surface and surface water resources. This appropriation is available until June 30, 2022, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

A Geologic Atlas provides the geologic framework of our state. It describes the materials and features at the land surface and extends all the way down to the bedrock surface. An atlas provides information useful for resource management and land-use planning. Each Atlas typically requires more than 7,000 person-hours of work. Some of that work is in the field: drilling test borings, examining, sampling, and describing outcrops. Much of the work follows after: interpreting field measurements, recognizing and formally naming geologic units described in well records, and making maps. The result is a detailed account of the distribution and properties of the rock and sediment that lie below the land surface. These materials, and their ability to store or transmit water, determine where we can find water, and how we can protect and make wise use of that water. This includes our lakes and rivers as well as groundwater.

As part of this 2018 award, we completed Kandiyohi County, started work in Cook, Yellow Medicine, Polk and Chippewa counties, and continued working in 11 other counties. We've described hundreds of outcrops, taken thousands of hand samples, and drilled nearly 30 continuous cores allowing us to sample rocks and sediment up to 325 ft deep.

We completed the equivalent of about 4 atlases with the ML 2018 funds, which were exhausted in one year of spending. This represents a higher number of atlases completed than our average of 5 atlases a year with all (CWF, DNR, and ENRTF) funds combined.

Continuing under the M.L 2019 award, atlases for Rock and Nobles counties will be complete within the next 3 months. Aitkin, St. Louis, Lake, and Steele counties should be finished within the next 12-18

months. The County Geologic Atlas program began in 1981 and continues with support of the Environment and Natural Resources Trust Fund as well as the Clean Water Fund, the Department of Natural Resources, and the U.S. Geological Survey. To date we have completed atlases for 43 counties, 23 are underway; and 21 have yet to be started. All of our mapping products and data are available in print or digital format.

PROJECT RESULTS USE AND DISSEMINATION

Every atlas is produced in portable document format (PDF), as geographic information system files (GIS), and in printed form. The digital files are available as a DVD, and are also available from the University of Minnesota Digital Conservancy, and via link from the MGS web page. Each project culminates with a meeting held in the project area to present the results to the county staff, and any other interested parties. At these meetings the products are described, access to the products is explained, and examples of applications of the products to common resource management situations are demonstrated. The products of subprojects in St. Louis and Lake counties are being released in digital form immediately following technical review. When all the subproject areas are complete county-wide compilations will be created and distributed digitally and in print. The printed copies are shared with the county, who in turn can distribute them to libraries, schools, townships, and other agencies. They are also distributed by the MGS map sales office. Products are also made available to earth science teachers and other educators for classroom exercises. Atlas products are also displayed and explained at educational events for SWCD staff and onsite sewage treatment system contractors.

Kandiyohi County Geologic Atlas is available online through the University of Minnesota Libraries Digital Conservancy. Interim products that will become the St. Louis and Lake County Atlases are also available online. Completed atlas products have been posted to the MGS website and linked to the University's Digital Conservancy as noted above. PDF products as well as all of the related GIS data are available on these pages.

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

Project Completed: 6/30/2022 **FINAL REPORT**

Develop a System to Assess Wildlife Health Threats in Minnesota

Research Project

Subd. 03f $280,000 TF

Kimberly VanderWaal
U of MN
1365 Gortner Ave
St. Paul, MN 55108
Phone: (530) 204-8555
Email: kvw@umn.edu
Web: https://www.raptor.umn.edu/

Appropriation Language
$280,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a statewide information-management system that uses wildlife-rehabilitation data to identify emerging threats to wildlife health in Minnesota

OVERALL PROJECT OUTCOME AND RESULTS

Identifying population health threats in wildlife over time and space is challenging, as data collection can be expensive and time-consuming. An alternative solution is to use existing primary care data from wildlife rehabilitation centers, which can act as sentinels. Establishing an information management and alert system to monitor wildlife health by merging databases of the two major wildlife rehabilitation centers of Minnesota. Use of the database to investigate environmental and land-use drivers of wildlife health.

The electronic databases of The Raptor Center and Wildlife Rehabilitation Center were merged into one database, which is set to be supported by the database server of the University of Minnesota. An online dashboard platform was created to facilitate visualization and descriptive analysis of the submissions. The dashboard is comprised of location maps and temporal graphs with the option to sort according to date range, species groups, location, clinical and diagnostic characteristics, resolution, and the circumstance that lead to the wildlife submissions, including entrapment and habitat destruction. Anomalies of submissions, i.e. more submissions from a specific area within a short span of time than expected, assessment was done using spatial scan statistics. This approach of anomaly detection may help clinicians to investigate, conduct surveillance, and be vigilant about emerging threats to wildlife health. While the anomaly detection is not featured in the online dashboard, the research provides a 'baseline' of expected seasonality and space-time patterns of submissions.

The project lead to increased collaboration between clinicians and researchers, and opportunity to use population statistics in their work. Understanding the species group-specific seasonality and space-time patterns of all species groups collectively provides a unique opportunity to monitor the population health trends, investigating drivers including environmental and land-use changes, and eventually informing Minnesotans to be in alert and take actions to improve wildlife health.

PROJECT RESULTS USE AND DISSEMINATION

The online dashboard has been shared with both the centers and a virtual meeting participating researchers of the University of Minnesota, developers of Epi Interactive of New Zealand (collaborator), and the clinicians from the two wildlife rehabilitation centers was held in May, 2020 to demonstrate the functionality of the dashboard.

Three scientific manuscripts are in being prepared in relation to this project and they are intended to be submitted to peer-reviewed journals for publication: Dashboard development, Spatiotemporal patterns of wildlife health, and Monitoring West Nile virus in the metro area of Minnesota.

Dashboard development: The manuscript would describe the importance of using existing databases as a potential passive surveillance or sentinel system to recognize wildlife health threats. The details would include database merging process, geocoding options (recognizing the submission location based on the provided address or location description), and the steps in development of the dashboard.

Spatiotemporal patterns of wildlife health: The manuscript would describe time-series and spatiotemporal analytical methods that were used to determine seasonality of submissions and the 'expected' numbers of submissions. Moreover, the manuscript would describe a novel approach to detect space-time anomalies where multiple species groups were submitted from the same area within a short span of time compared to the expected 'baseline'. This method of detecting 'cluster submissions' also supports determining the key drivers led to submissions such as habitat-destruction. The manuscript would describe the method using a subset of data from both the centers and relevant examples of temporal patterns and 'cluster submissions'.

Monitoring West Nile virus in the metro area of Minnesota: The manuscript and the data analysis intends to demonstrate spatiotemporal patterns of West Nile virus (WNV) detected in mosquito, bird, animal, and human populations focusing on the seven-county metro area of Minnesota. This disease specific research project extends the proposed utility of existing wildlife rehabilitation data and bring other parallel databases together for the analysis. The collaborators who contribute with relevant data are Minnesota Department of Health (MDH) providing human data, Minnesota Board of Animal Health (MNBOAH) providing animals detected with WNV such as horses, and Minnesota Mosquito Control District (MMCD) providing the data relevant to mosquito surveillance. The research project is currently at the analytical stage.

Project Completed: 6/30/2020 **FINAL REPORT**

Subd. 05 Technical Assistance, Outreach, and Environmental Education

Prairie Sportsman Statewide Environmental Broadcasts and Videos

Subd. 05a $300,000 TF

Cindy Dorn
Pioneer Public Television
120 W Schileman
Appleton, MN 56265
Phone: (651) 239-3995
Email: cdorn@pioneer.org
Web: http://www.pioneer.org

Appropriation Language
$300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Pioneer Public Television to provide outreach on outdoor recreation, conservation, and natural resource issues, including water quality, wildlife habitat, and invasive species, through a series of interrelated educational and training videos and statewide broadcast television programs.

OVERALL PROJECT OUTCOME AND RESULTS

Prairie Sportsman celebrates our love of the outdoors. As Minnesotans spend more time with digital media, this Pioneer PBS production uses screen time to promote connecting to our natural world through outdoor sports, recreation and environmental stewardship. It provides engaging environmental science education and ways for individuals, communities and organizations to restore and protect natural resources. Prairie Sportsman's reach is statewide, airing on all Minnesota PBS stations.

The 26 episodes produced by this project include 26 environmental, 26 outdoor lifestyle and 26 citizen action segments. Conservation topics include habitat restoration for pollinators, prairie chickens, ruffed grouse and native mussels and restoration of endangered species such as peregrine falcons, trumpeter swans, river otters and Dakota Skipper butterflies. Prairie Sportsman highlighted Dave Mech’s wolf research, Carrol Henderson’s long career as the first DNR Nongame Wildlife Research Supervisor and the Naamijig Dance Troupe tribute to long-time grouse researcher John Toepfer. Other topics include the perennial wheatgrass kernza, removal of Minnesota River and Red River basin dams to improve fish habitat, chronic wasting disease in deer, removing silt to restore shallow lakes, grazing bison to restore oak savanna, sturgeon tagging, employing sled dogs in U.S. Forest Service work and testing lake oxygen. Prairie Sportsman brought viewers to places like the International Wolf Center, Touch the Sky Prairie, Lost 40 SNA, Gopher Campfire Wildlife Sanctuary and the wild and scenic St. Croix River. A full episode

was dedicated to southeast Minnesota's Driftless Area, featuring trout streams, restored blufflands, timber rattlesnakes and Mystery Cave. The environmental segment "Pollinator Friendly Solar" was awarded an Upper Midwest Emmy and segments on the National Eagle Center's golden eagle studies and TUNE youth outdoor camp received nominations.

Pioneer PBS has invested ENRTF funds in content that inspires Minnesotans to connect with the outdoors and protect precious natural resources.

PROJECT RESULTS USE AND DISSEMINATION

Prairie Sportsman has statewide appeal and is aired on all Minnesota PBS stations, including Pioneer PBS (Granite Falls), Lakeland PBS (Bemidji and Brainerd), WDSE (Duluth), tpt (Twin Cities PBS) and KSMQ (Austin).

In addition, each episode's three video features are segmented and individually branded to stand alone. Full episodes and individual segments continue to be viewed online at prairiesportsman.org, Facebook and YouTube. The evergreen episodes are produced to have long-term educational value for schools, environmental learning centers, natural resource agencies, outdoor sports and recreation groups, civic organizations and individuals. After each season, complimentary DVDs are offered to all who participated in or helped with video features and, this year, Pioneer PBS received requests for almost 250 videos. The attached spreadsheets show all the episodes and segments produced in 2019 and 2020 and the people and organizations across Minnesota involved in creating these features.

The program's aggressive social media campaign brings awareness to each episode and individual segments that will draw people to view them online. Facebook has been the most successful social media platform for marketing Prairie Sportsman, with more than 4,000 dedicated followers. Instagram and Snapchat have also helped expand Prairie Sportsman's audience.

Project Completed: 6/30/2020 **FINAL REPORT**

Update International Wolf Center Exhibits

Subd. 05i $1,000,000 TF

Rob Schultz
International Wolf Center
7100 Northland Circle N, Ste 205
Brooklyn Park, MN 55428
Phone: (763) 560-7374 x222
Email: rob@wolf.org
Web: http://www.wolf.org

Appropriation Language
$1,000,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the International Wolf Center to design, construct, and install new interactive educational exhibits to help Minnesotans understand coexistence with the state's wolf populations and ongoing wolf- management efforts.

OVERALL PROJECT OUTCOME AND RESULTS

Since 1993, over one million people have learned about wolves at the International Wolf Center's interpretive center in Ely. The Center's old exhibit was created in the early 1980's, its purpose was to promote species survival. Although beautifully and professionally created, the success of wolf recovery

over the past three decades in Minnesota has resulted in it becoming outdated. Display materials were made with a high-quality printing process on permanent materials, making it cost-prohibitive to update exhibit displays.

The New Exhibit has three main components: 1) History of Wolves 2) Science of Wolves: Their Biology and Role in Nature as an Apex Predator and 3) Co-Existence with Wolves: The Need for Wolf Management. The exhibit is equipped with interactive state of the art technology to optimize the learning experience. A "Howling Room" sound chamber simulates an outdoor experience where visitors will learn how to communicate with packs. Through immersive experiences, visitors will learn about the complicated issues in Minnesota surrounding human interactions with wolves.

The exhibit, known as Discover Wolves! informally opened to the public beginning on Friday, May 10th. The official, large public grand opening celebration occurred on Friday, June 28th. The finished Discover Wolves! exhibit will teach tens of thousands of Minnesotans and people around the world who visit the interpretive center the facts about wolf biology, management and recovery.

PROJECT RESULTS USE AND DISSEMINATION

Updates about the progress of the new exhibit were shared each month on the International Wolf Center's social media platforms and through electronic mailings. In April, Executive Director Rob Schultz appeared before the Ely City Council and gave an update on the progress of the new exhibit. Updates of the progress of the exhibit preparations were shared with news media throughout the spring months, and the Center received publicity in regard to the new exhibit upon completion of its installation in May.

An article giving updates about the new exhibit was published in International Wolf Magazine in mid-May. Additional items planned include news releases being prepared that highlight the grand opening celebration, as well as a final article about the completion of the new exhibit that will appear in International Wolf Magazine in mid-August.

Project Completed: 6/30/2020 **FINAL REPORT**

Subd. 09 Land Acquisition, Habitat, and Recreation

Harmony State Trail Extension Land Acquisition

Subd. 09c $235,000 TF

Jerome Illg
City of Harmony
225 3rd Ave SW, PO Box 488
Harmony, MN 55939
Phone: (507) 886-8122
Email: cityoffice@harmony.mn.us
Web: http://www.harmony.mn.us

Appropriation Language
$235,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the city of Harmony to acquire fee title of about 16 parcels to allow for the approximate six-mile extension of the legislatively authorized state trail from Harmony south to the Iowa state border with a spur to Niagara Cave. The land must be transferred to the state after it has been purchased.

OVERALL PROJECT OUTCOME AND RESULTS

Originally conceived as a part of the Governor's Design Team project in 1989, the extension south to the Iowa border and Niagara Cave was the next segment to be constructed of the Harmony-Preston Valley State Trail. Since the completion of the existing segment in the mid-90s, local volunteers worked with landowners to extend the trail south from Harmony to the major tourist attraction, Niagara Cave, and the Iowa border where the trail system from northeast Iowa will connect to create an interstate trail system.

Local volunteers secured option contracts on 16 parcels to secure the land corridor necessary for the approximately 6-mile trail. The options were set to expire on December 31, 2019. LCCMR funding was secured in 2018 to provide a funding source to exercise the options and purchase fee title what ended up being portions of 20 parcels. This acquired land will be donated to the Minnesota Department of Natural Resources per the authorizing legislation.

This funding provided in this project will allow for the construction of the state trail extension, which is to be completed in 2021. Once completed, this project will provide a recreational opportunity to regional residents and visitors from both in and outside of Minnesota; promoting outdoor recreation, health, and enjoyment of southeastern Minnesota natural resources.

PROJECT RESULTS USE AND DISSEMINATION

No materials were created to promote or disseminate information about this project as it was purely related to land acquisition.

This project was mentioned in local media reports including newspapers and television news. All reports mentioned that funding was made possible through a grant from LCCMR and the Harmony Area Community Foundation. "Funding provided by" signage utilizing the trust fund logo will be placed on the bike trial route.

Project Completed: 6/30/2020 **FINAL REPORT**

Enhancement Plan for Superior Hiking Trail

Subd. 09f $100,000 TF

Denny Caneff
Superior Hiking Trail Association
731 Seventh Ave, PO Box 4
Two Harbors, MN 55616
Phone: (218) 834-2700
Email: hike@shta.org
Web: http://www.shta.org

Appropriation Language
$100,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Superior Hiking Trail Association to evaluate improvements to the 310-mile-long Superior Hiking Trail including routing, safety, water management, maintenance, and other environmental, recreational, and design issues and to develop an interactive trail-management system to capture efficiencies and best management practices.

OVERALL PROJECT OUTCOME AND RESULTS

This LCCMR grant allowed SHTA to conduct assessments by professional trail builders and ecologists, focusing on the most worn-out sections of the Trail. The grant also allowed us to build a trail database – a repository for all relevant documents of the SHT and a place to catalog work projects.

All users of the SHT will benefit from a better built and more resilient Superior Hiking Trail. Their experience should be more pleasant and safer. The SHT is a Minnesota recreational icon; everyone is rooting for its continued existence and good health.

Our database is in use almost daily; it was not intended for dissemination or use outside the SHTA. The trail assessments were heavily scrutinized internally and shared with the affected resource professionals. The educational videos are online for the public. The volunteer manual, once finalized, will serve hundreds of SHTA volunteers and set a new standard for trail maintenance.

PROJECT RESULTS USE AND DISSEMINATION

We generally don't make the assessment reports public, but we do provide them to people who ask for them. We certainly supply the state park officials with these assessments.

The videos we produced are on the internet for the world to see. The volunteer trail maintenance manual will be distributed to the hundreds of volunteers who put in time on the SHT. The videos and the manual contain/will contain the requisite language explaining the support of the ENRTF grant.

Project Completed: 6/30/2020 **FINAL REPORT**

Protecting Mississippi River Headwaters Lands through Local, State, and Federal Partnership

Subd. 09g $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).

Project due to be completed: 6/30/2020 **Work Plan**

Subd. 12 Contract Agreement Reimbursement

Contract Agreement Reimbursement

Subd. 12 $135,000 TF

Katherine Sherman-Hoehn
MN DNR
500 Lafayette Rd, Box 10
St. Paul, MN 55155
Phone: (651) 259-5533
Email: Katherine.Sherman-Hoehn@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$135,000 the second year is from the trust fund to the commissioner of natural resources, at the direction of the Legislative-Citizen Commission on Minnesota Resources, for expenses incurred for preparing and administering contracts for the agreements specified in this section. The commissioner must provide documentation to the Legislative-Citizen Commission on Minnesota Resources on the expenditure of these funds.

OVERALL PROJECT OUTCOME AND RESULTS

This appropriation was used to support the ENRTF contract management program, which ensured that ENRTF grantees expended grant funds in compliance with state law, session law, approved work plans, and Office of Grants Management grants policies.

The DNR Grants Unit managed 71 grants active in FY 2019. In FY 2020, the Grants Unit managed 72 active grants.

Between 1/1/2019 when billing began and 06/30/2020 when it ended, the DNR Grants Unit:

- Made 194 reimbursements to grantees totaling $7,702,401
- Finished executing 25 ML 2019 grant agreements
- Prepared 18 grant amendements for ENRTF grants extended due to COVID, including implementation of electronic signature process
- Billed 1,167 hours at the FY 2020 professional services rate of $66.00/hr and 906 at the FY2019 rate of $64/hr
- Monitored all grants in compliance with Office of Grants Management policies.

PROJECT RESULTS USE AND DISSEMINATION

Project personnel were in frequent contact with appropriation recipients and LCCMR staff. Information was disseminated through manuals, training sessions, orientations, meetings, memos, letters, emails, newsletter, and phone.

Project Completed: 6/30/2020 **FINAL REPORT**

1. M.L. 2017 Projects Completed
January 15, 2019 – January 15, 2021

MN Laws 2017, Chapter 96, Section 2

M.L. 2017 Projects

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

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

Subd. 03 Foundational Natural Resource Data and Information

County Geologic Atlases - Continuation

Subd. 03a $2,000,000 TF (FY2017)

Barbara A. Lusardi
U of MN - MN Geological Survey
2609 Territorial Rd
St. Paul, MN 55114
Phone: (612) 626-5119
Email: lusar001@umn.edu
Web: http://www.mngs.umn.edu

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

Project due to be completed: 6/30/2020 Work Plan

Minnesota Wildflowers Online Botanical Reference - Phase II

Subd. 03e $270,000 TF (FY2018)

Katy Chayka
MN Wildflowers Information
1590 Long Lake Rd
New Brighton, MN 55112
Phone: (651) 399-4064
Email: kchayka@c-net.us
Web: http://www.minnesotawildflowers.info/

Appropriation Language
$270,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Minnesota Wildflowers Information to continue surveying and imaging plant species and publishing species profiles for a plant identification reference Web site available to the public and land managers. Images acquired and information compiled using these funds are for purposes of public information available on a Web site. If the organization is no longer able to maintain the Web site, the organization must work with the state and the University of Minnesota, Bell Museum of Natural History, to ensure

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

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota Wildflowers, an online field guide to the plants of Minnesota, was launched in 2007 by an amateur botanist who grew frustrated with the lack of information and quality imagery specific to Minnesota's flora. The task of systematically seeking out each species, photographing the identifying characteristics, describing each in non-technical terms, and publishing on the web was undertaken with the goal of becoming a comprehensive reference for all of Minnesota's 2100+ plants. The need for such a reference, especially targeted to non-botanists, has been evident by the number and type of users of the website, virtually anyone asking such questions as: What is that plant? Is it native or a weed? How to distinguish it from similar plants? These users include natural resource managers, restoration specialists, educators from elementary school through university level, citizen scientists, native plant advocates, gardeners and the general public. In 2014 when initial funding began, 799 species (mostly forbs) had been published and the average traffic during peak season was 2,000 visits and 10,000 web pages viewed per day. During the 6-year funding period ending June 2020, the 2-member team traveled 65,000 miles visiting locations in nearly every Minnesota county, photographing over 1500 plant species. This field work resulted in significantly increased coverage. As of June 30, 2020, 1734 species have been published, 82% of all Minnesota’s vascular plants, including trees/shrubs, grass-like plants, ferns and aquatics. Traffic has more than tripled with average 8,000 visits and 33,600 pages viewed per day during 2020 peak season, increases of 60% and 45% respectively over 2017 when the second round of funding began. This clearly shows the website is a valued resource and the more species covered, the more valuable it becomes.

PROJECT RESULTS USE AND DISSEMINATION

Usage of the website continues to grow; expectations are we will reach 1 million users in 2020. While word-of-mouth and Google searches are the source of much traffic, our web statistics show the single highest usage continues to come from the State of Minnesota, which includes multiple state agencies as well as the University of Minnesota. Our plant images are in high demand for other educational and outreach purposes, including interpretive signs, PowerPoint presentations and invasive species fact sheets, all of which promote the project via photo credits. Our field work puts us in contact with many state parks, nature centers and educational institutions across the state where we promote the project to their staff and visitors. During the past 3 years we collaborated with the Minnesota Landscape Arboretum on their native plant program, began discussions with the Minnesota Nursery and Landscape Association Foundation on contributing to their botany-related educational curriculum, manned a booth at the international Botany Conference in Rochester, had an interview on CCTV, and gave presentations about the project to Audubon, Wild Ones, and several other clubs and organizations. A marketing postcard was also developed and distributed to nature centers, educators, organizations and businesses across Minnesota.

Project Completed: 6/30/2020 **FINAL REPORT**

Drainage Records Modernization Cost Share - Phase II

Subd. 03g $540,000 TF (FY2018)

Mark Hiles
Board of Water and Soil Resources

520 Lafayette Rd
St. Paul, MN 55155
Phone: (507) 766-9818
Email: Mark.Hiles@state.mn.us
Web: http://www.bwsr.state.mn.us

Appropriation Language
$540,000 the first year is from the trust fund to the Board of Water and Soil Resources to facilitate statewide modernization of public drainage records under Minnesota Statutes, chapter 103E, and integrate new specifications into existing drainage records modernization guidelines through matching cost-share grants to drainage authorities. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota has an estimated 20,000 miles of Minnesota Statutes Chapter 103E public drainage ditches (Public Drainage Ditch Buffer Strip Study, Feb. 2006), and estimated thousands of miles of Chapter 103E public subsurface tile systems. Records for these public drainage systems are kept by the current 96 drainage authorities (a drainage authority (DA) can be a county, joint county board, or a Watershed district). The drainage system records are in various conditions, including deteriorating hard copy materials and scanned documents with limited electronic access.

Use of consistent GIS database capabilities are needed to advance local management of public drainage systems and to improve public access to statewide hydrographic data. Hydrographic data about the location, type (ditch or tile), dimensions and profiles of public drainage systems are often sought for watershed modeling and water planning but have not been easily accessible. Several hundred systems records containing several thousands of miles of open ditch and tile have been scanned, indexed, digitized and uploaded to local drainage databases and GIS layers as well as MnGeo Commons website. Many of the drainage authorities have completed this work for all systems in their jurisdiction, some have plans to continue their efforts until all systems are complete. A summary of the accomplishments from each grantee is in the attached spreadsheet.

PROJECT RESULTS USE AND DISSEMINATION

All grantee organizations and hydrography data can be found at the Minnesota Geospatial Commons public website. This link provides one location to find all the individual datasets. It lets people find the GIS data from which maps could be made, but there are no ready-made maps. In addition, all organizations have updated and posted easily accessible information on their organizational website and a link has been provided on the BWSR Drainage Records Modernization webpage. This has advanced local drainage records preservation and use for enhanced drainage system management and provided hydrographic data about these drainage systems in the statewide GIS database.

Project Completed: 6/30/2020 **FINAL REPORT**

Groundwater Contamination Mapping

Subd. 03h $400,000 TF (FY2018)

Hans Neve
Minnesota Pollution Control Agency
520 Lafayette Rd
St. Paul, MN 55155

Phone: (651) 757-2608
Email: hans.neve@state.mn.us
Web: https://www.pca.state.mn.us/waste/superfund-program

Appropriation Language
$400,000 the first year is from the trust fund to the commissioner of the Pollution Control Agency to develop a Web-based interactive map of groundwater contamination to improve protection of groundwater resources for drinking water. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

In Minnesota 75% of the drinking water comes from groundwater, a source that is generally out of sight and out of mind. Minnesota properties that were once home to dry cleaners, metal plating shops, manufacturing plants and other industrial facilities in many cases have contaminated our groundwater from spills and leaks of hazardous chemicals. Frequently the contamination spreads off the property creating an area of groundwater contamination. When there has been contamination often costly treatment systems are needed to make the water suitable for use.

Information about the areas of groundwater contamination were contained in individual MPCA Superfund Program project files. The project was developed to expand access to information about groundwater contamination to improve protection of groundwater resources.

This project developed the Minnesota Groundwater Contamination Atlas. The Atlas maps areas of groundwater contamination concern and tells the contamination story in a way that is understandable to the general public and is meaningful for technical users. The Atlas also makes it easy for the public to download contamination testing results from individual wells. The Atlas establishes a public communication platform that can be expanded beyond the 92 superfund sites that were included in this project.

The project extracted well information from project files and loaded it into a state enterprise database,13,605 wells and loaded 3,700 groundwater contamination test results were loaded into the database. The data was used to map 92 contamination source areas and 60 distinct groundwater contamination areas of concern. For each source areas a contamination site story tells how the contamination happened, what the contaminants are, what cleanup work has been done, what additional cleanup work is planned, where drinking water in the area comes from, who to contact with questions and if there is related contamination in soil, sediments and underground vapor. A project development webpage and stakeholder group were utilized to help shape scope and format of the map contamination story elements of the Atlas.

PROJECT RESULTS USE AND DISSEMINATION

A project webpage was used to provide project development updates and solicit stakeholder feedback as project elements were developed. The webpage invited interested parties to subscribe to the GovDelivery email distribution list for the project. The GovDelivery list currently includes 832 subscribers. Outreach during the project also include presentation at professional conferences and stakeholder meetings. A recorded presentation of the project presentation at that 2019 Minnesota Groundwater Association (MGWA) Fall Conference “No Longer ‘out of Sight, Out of Mind- Making Groundwater Science Visible to Citizens and Clients” is available on the MGWA website.

Launch of the Minnesota Groundwater Contamination Atlas was communicated through the project Gov Delivery distribution list as well as MPCA social media platforms. As of August 3rd the Minnesota Groundwater Atlas website has been visited by 1,162 non-MPCA users.

Project Completed: 6/30/2020 **FINAL REPORT**

Moose Calf Surveys and Monitoring

Subd. 03j $348,000 TF (FY2018)

Dr. James D. Forester
U of MN
2003 Upper Buford Cir, 135 Skok Hall
St. Paul, MN 55108
Phone: (612) 626-6721
Email: jdforest@umn.edu

Appropriation Language
$348,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to assess the use of unmanned aerial vehicles in natural resource monitoring of moose populations and changes in ecosystems.

Project due to be completed: 6/30/2019 **Work Plan**

Subd. 04 Water Resources

Assessment of Household Chemicals and Herbicides in Rivers and Lakes

Research Project

Subd. 04a $236,000 TF (FY2018)

William Arnold
U of MN
500 Pillsbury Dr. SE
Minneapolis, MN 55455
Phone: (612) 625-8582
Email: arnol032@umn.edu
Web: http://personal.ce.umn.edu/~arnold/

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

OVERALL PROJECT OUTCOME AND RESULTS

Quaternary ammonium compound (QACs) are ingredients in personal care products, fabric softeners, disinfectants, and herbicides. QACs, which are biologically active molecules, are unintentionally and intentionally released into the environment. QACs kill bacteria and may affect microbial communities in wastewater treatment and algal communities in surface waters. In this study, the levels of QACs in the effluent from 12 wastewater treatment plants were determined. Plants with more advanced treatment processes had lower levels of QACs. Sediment samples in a lake demonstrated potential inputs from both municipal wastewater effluent and agricultural sources for QACs. In sediment cores taken from lakes, two distinct trends over time were observed. In lakes with large watersheds and mixed domestic

and industrial wastewater sources, peak concentrations of QACs were found at depths corresponding to deposition in the 1980s and decreases after this time are attributed to improved wastewater treatment and source control. In a smaller lake with predominantly domestic wastewater inputs, concentrations of QACs increased slowly over time. In surface waters, QACs were found to degrade by reaction with reactive species (hydroxyl radicals) generated by sunlight and by microbial processes. Even with these loss processes, QACs likely persist from days to weeks in the water, leading to their deposition in the sediments. QACs were found to form low levels of a carcinogenic class of compounds (nitrosamines) when reacted with a drinking water disinfectant (chloramine), but this would be of greatest concern in wastewater potable reuse scenarios. The overall results of the work indicate that QACs are being released by wastewater treatment plants. Once in the environment, degradation by bacteria and by sunlight can occur in surface waters, but accumulation in sediments, where the QACs are persistent, is likely the main removal process. During the wastewater disinfection process QACs can form a carcinogen, but QACs are not as important as other chemicals known to form nitrosamines. The findings allow more robust assessment of potential impacts of QACs and insight into wastewater treatment processes that lead to removal, which is important given the increasing use of QACs during the COVID-19 pandemic.

PROJECT RESULTS USE AND DISSEMINATION

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

Project Completed: 6/30/2019 **FINAL REPORT**

Assessment of Water Quality for Reuse

Subd. 04f $148,000 TF (FY2018)

Satoshi Ishii
U of MN
1479 Gortner Ave, 140 Gortner Labs
St. Paul, MN 55108
Phone: (612) 624-7902
Email: ishi0040@umn.edu

Appropriation Language
$148,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to collect and analyze pathogen data for evaluation of water reuse in order to maximize water reuse and protect groundwater and surface water quality.

OVERALL PROJECT OUTCOME AND RESULTS

Reusing water will reduce demands on groundwater aquifers and improve surface water quality. However, public perception of health risks associated with microbiological contaminants remains a key barrier to the expansion of water reuse. The goal of this project is to maximize the potential of water reuse in Minnesota by eliminating barriers to water reuse implementation. In this project, water quality of 25 water reuse systems around Minnesota was assessed by quantifying potential human pathogens. At each reuse facility, water samples were collected at the source and when available at the distribution

site such as an irrigation tap. When treatment steps were in place, water samples were also collected before and after the treatment. Samples were collected more than once for some reuse facilities. As a result, 90 water samples were collected from the 25 sites. Bacterial and viral pathogens in these water samples were quantified using a high-throughput method. Most of the water samples did not contain detectable levels of pathogens. Some pre-treatment wastewater samples, contained potential human pathogens such as norovirus. Based on a preliminary quantitative microbial risk assessment (QMRA) for norovirus, the risk for illness and infection is considerable for these samples. However, advanced water treatment removed these pathogens to the levels considered low risk of infection and illness for reuse. Due to the complexity of QMRA analyses and the variability of the results, the risk assessment is only done for norovirus. Potential health risks associated with pathogens other than norovirus should be analyzed in the future.

PROJECT RESULTS USE AND DISSEMINATION

This project has produced two presentations: one at the EPA's webinar on "Water Reuse and Reclaimed Water" and one at a national conference (Association of Environmental Engineering and Science Professors [AEESP] Conference). Two publications are being prepared: one as a peer-review journal publication and one as a white paper published from Minnesota Department of Health. These publications will be freely available to the public.

The outcomes of this research have been used to expand our water reuse research. MN Stormwater Research Council has provided additional funding to continue and expand the water reuse research. In addition, the outcome obtained in this project will be shared with other state and federal agencies (EPA, MPCA, etc.) as well as private sectors to establish safe water reuse in MN and other states.

Project Completed: 6/30/2019 **FINAL REPORT**

Identification of Chemicals of Emerging Concern in Minnesota Fish

Research Project

Subd. 04g $400,000 TF (FY2018)

Seth Moore
Grand Portage Band of Lake Superior Chippewa
27 Store Rd
Grand Portage, MN 55605
Phone: (218) 370-9310
Email: samoore@boreal.org

Appropriation Language
$400,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Grand Portage Band of Lake Superior Chippewa to identify chemicals of emerging concern and metals in fish, water, and sediments from approximately 30 water bodies in northeastern Minnesota used for subsistence harvest and recreation. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This is the first study to comprehensively analyze a large suite of Chemicals of Emerging Concern (CECs) across the three media of fish tissues, water, and sediment in a broad geographic extent in northern Minnesota. CEC's are pharmaceuticals and personal care products that can linger in the environment

and have been shown to affect behavioral and reproductive health of aquatic life. This study was focused on fish species and water bodies used for subsistence by the Grand Portage Band of Chippewa and recreational users of northeastern Minnesota. We described the spatial distribution of CEC occurrences in 25 Minnesota lakes and in Lake Superior. We consider our most important findings to be the number of detections and the classes of CECs that were detected. We found 117 CECs across all media types with 101 found in water samples, 67 in sediments, and 35 in fish tissues. The pharmaceutical classes that were most frequently detected included hormones (100% of sites), DEET insect repellent (100% of sites), antidepressants (80% of sites), and antimicrobials (80% of sites). These results were derived from surface water samples, sediment samples, and fish samples of walleye/yellow perch in inland lakes and lake trout/cisco from Lake Superior. We also related measures of fish health and parasite loading to CECs and land use. Our findings are consistent with early literature on CECs in Minnesota lakes that studied water samples only. We used Aquatic Toxicity Profiles (ATPs) to identify those chemicals that may pose risks to aquatic life. ATPs provide an overview of chemical-specific information such as acute toxicity, endocrine activity, physicochemical properties, and occurrence information in the aquatic environment. We found that even in undeveloped sites that had a fewer number of total contaminants, they often had a high percentage of high priority contaminants. More work is needed to determine the effects of CECs on aquatic life.

PROJECT RESULTS USE AND DISSEMINATION

A video was developed from this project and posted to YouTube. There were three radio broadcasts on this work, WTIP, Grand Marais in 2016, WTIP, Grand Marais in 2017, and Minnesota Public Radio (MPR) in 2020. Various online and paper media outlets reported on this work as well including: The Circle (Part One and Part Two of their two-part series), The Minnesota Daily, University of Minnesota College of Veterinary Medicine News, Medium, City Pages, and the Grand Rapids Herald Review.

Project Completed: 6/30/2020 **FINAL REPORT**

Techniques for Water Storage Estimates in Central Minnesota

Subd. 04h $250,000 TF (FY2018)

John Nieber
U of MN
1390 Eckles Ave, Rm 203
St. Paul, MN 55108
Phone: (612) 625-6724
Email: nieber@umn.edu
Web: https://wiki.umn.edu/view/Water_Sustainability

Appropriation Language
$250,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to improve water storage estimates in groundwater, soil moisture, streams, lakes, and wetlands through integration of satellite monitoring and ground-based measurements in central Minnesota. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Our freshwater resources reside in surface water bodies (ponds, wetlands, lakes, streams/rivers) and subsurface water reservoirs (soil and groundwater aquifers). Management of these freshwater

resources has always been a challenge because we do not have a good idea of how much water is stored in these various entities. The objective of this project was to improve the methods for real-time quantification of the amount of water stored in these entities using existing ground-based measurement networks as well as satellite data. The study region stretched from St. Paul to Moorhead, and encompassed 17 HUC-8 watersheds. The study region has an area of about 53,000 km3. We collected archived ground-based measurements including streamflows, observation wells, and lake levels for the period 2002-2015. We also acquired satellite data from the GRACE (Gravity Recovery and Climate Experiment), SMOS/SMAP, and Landsat satellites. The GRACE satellite provides data on the total water stored in the earth. The spatial resolution of the data used in this study was 100 km by 100 km. The SMOS/SMAP satellites provide a measure of the surface soil moisture over areas of about 36 km by 36 km. The Landsat satellite provides visual images at a scale of 30 m, and can be used for measuring the surface area of individual lakes; this surface area data can be used to estimate the volume of water stored in a given lake at a given moment in time. The project demonstrated that the variation in total water storage can be monitored by the GRACE satellite, and variations in lake storage can be monitored by the Landsat satellite. For the period 2002-2015 the estimates of time-averaged water storage is 1,500 km3 for groundwater in the Quaternary (surficial) aquifer, 15 km3 for lakes, 20 km3 for soil moisture, and 1.5 km3 for wetlands. The GRACE satellite became inoperable in late 2017, far exceeding the original planned life for the satellite. However, in May 2018 a new satellite, GRACE-FO (GRACE-Follow On) was launched and it now is providing the same information about total water storage. One of the outcomes of this project is a new research activity to test the utility of water storage information gained from the GRACE-FO satellite to forecast flooding and hydrological droughts in Minnesota.

PROJECT RESULTS USE AND DISSEMINATION

The project results have been presented at a number of different forums including the Minnesota Water Resources Conference (October 2019), the Water Resource Sciences Graduate Seminar at the University of Minnesota (September 2019), and the Western Regional Project 4188 Meeting in Las Vegas (January 2020). Two MSc theses were completed based on the work in the project, and the work of two Ph.D. students got started (one to finish in December 2020 and the other to finish in December 2021) based on work in the project.

A methodology for quantifying the volume of water in a lake based on the surface area of a lake was adapted from previous work and was tested during this project for the project study region. This tested methodology was then used in a separate LCCMR funded project in which the volumes of lakes across the State of Minnesota were estimated. This objective of this other project was to use remote sensing to quantify the water quality of lakes and the lake volume estimates were needed to examine lake processes affecting lake water quality.

A methodology was developed for quantifying the volume of water stored in the Quaternary aquifer spanning across the study region. The methodology uses observation well data and lake level data to map the water table across the region. This methodology will be shared with the MNDNR, but also it will also now be used in some immediate future research to assess the water table mapping in quantifying the forecasting of floods, and possibly in forecasting hydrologic droughts.

Project Completed: 6/30/2020 **FINAL REPORT**

Subd. 05 Environmental Education

Expanding Raptor Center Online Education

Subd. 05d $270,000 TF (FY2018)

Julia Ponder
U of MN
1920 Fitch Ave
St. Paul, MN 55108
Phone: (612) 624-3431
Email: ponde003@umn.edu
Web: http://www.TheRaptorCenter.org

Appropriation Language
$270,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Raptor Center, to provide environmental education for approximately 15,000 middle-school students and 600 teachers, combining classroom learning and outdoor experiences with technology, scientific investigation of birds, and conservation projects. This appropriation is available until June 30, 2022, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

If Minnesota students are to grow into adults who are capable of making meaningful contributions to conservation, both they and their teachers need effective tools to foster meaningful outdoor experiences. This project expanded Raptor Center Online Education to give both teachers and students those much-needed tools with a goal of facilitating experiential outdoor learning and inspiring conservation mind-sets.

The major project objectives were to expand a current education program (Raptor Lab) to support students in conducting an investigation, provide teachers with demonstrations on how to use the learning module, and bring in environmental education experts to teach teachers skills and techniques to facilitate meaningful outdoor learning experiences for their students.

We partnered with University of Minnesota Extension and Learning Technologies Media Lab to build an interactive environment for students, based on a proven curriculum developed by Extension, Driven to Discover. We created a web-based interactive version titled “Outdoor Investigator.” Outdoor Investigator is six-part educational tool engaging students, step-by-step, though the scientific method to complete an outdoor investigation.

Once Outdoor Investigator was completed, The Raptor Center, Extension, Eagle Bluff and Wolf Ridge worked together to design and develop teacher demonstrations. Demonstrations explored each section of Outdoor Investigator, the technology and functionality of the online environment, integrated outdoor teaching techniques, and expanded Teacher Toolbox with extra materials and resources. Three model conservation projects were also created and included in the Teacher Toolbox to guide teachers in the process of conducting a Citizen Science-based outdoor investigation.

Over the course of the 2018 – 2019 school year demonstrations were provided to 520 teachers in 28 counties throughout Minnesota. These teachers will serve an estimated population of 15,000 to 25,000 students. Minnesotans will benefit from this work when as many as 25,000 children a year, throughout the state of Minnesota, engage in authentic and meaningful learning experiences in their local environment to inspire our next generation of scientists and future conservationists.

PROJECT RESULTS USE AND DISSEMINATION

Throughout the two year grant period we have been intensively disseminating Outdoor Investigator in a number of venues where we would be interacting directly with teachers. We presented and/or

exhibited at numerous conferences, such as Minnesota Education Academy Conference (MEA), the Minnesota Science Teachers Association Conference, Sci/Math and Ignite After school conference, the Agriculture Teachers Tech Conference, Minnesota Association of Agricultural Educators, the Conference of Middle and High School Principles, Minnesota's Grand Challenges Conference at the University of Minnesota, the Minnesota Department of Natural Resources Forest School Program Conference, the 3M Visiting Wizards Teacher's Workshop (hosted by 3M), Bell Museum's Educator's Open House, Prior Lake Teacher Development Workshop, University of Minnesota Extension Driven to Discover Teacher Training, and the Minnesota Field Trip Fair.

During these exhibits we had printed materials to highlight the main components of Outdoor Investigator, a computer for teachers to see and interact with the Raptor Lab and Outdoor Investigator, and forms to capture teacher information to contact them directly with information to access the website and to communicate important information about upcoming Teacher Demonstrations.

Project Completed: 6/30/2019 **FINAL REPORT**

Increasing Residential Environmental Learning Center Opportunities

Subd. 05g $130,000 TF (FY2018)

Bryan Wood
Osprey Wilds Environmental Learning Center
54165 Audubon Dr, PO Box 530
Sandstone, MN 55072
Phone: (320) 245-2648
Email: bwood@audubon-center.org
Web: http://www.audubon-center.org

Appropriation Language
$130,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Audubon Center of the North Woods to provide scholarship opportunities for a minimum of 1,000 students that are not currently served through other residential environmental education learning centers. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Today's students are increasingly being left out of nature learning experiences with children today spending far less time outdoors than any other generation in human history. For students that are low on the socio-economic spectrum, this is compounded as there are typically no outdoor areas near where they live, or adults who spend time with them in natural areas. Many schools do not have the financial resources to make environmental field trips possible. Additional factors impeding their participation are the cultural and language barriers increasingly seen with immigrant populations. Parents do not understand what the experience is, and are wary of sending their child away on an overnight field trip. Students coming from low economic families cannot afford to pay the student fee, or buy winter outerwear or a sleeping bag for use in the dormitory. We as a society have a responsibility to foster environmentally literate citizens from all backgrounds and it starts with our children. They will make the decisions for our society's future.

We wanted to engage with the diverse and changing demographics of MN's schools through this project by offering scholarships to financially strained schools to attend Osprey Wilds Environmental Learning

Center for environmental learning experiences. This project's goal was to make residential environmental learning experiences more accessible by: 1) providing a minimum of 1,000 K-12 scholarships to Minnesota students for residential programming at Osprey Wilds Environmental Learning Center, 2) purchasing outerwear (snow pants, coats, hats, mittens, scarves, winter boots) to lend out to K-12 students when attending to keep them comfortable and safe, 3) translating all K-12 trip forms into Spanish, Hmong, and Somali.

Through this project, we were actually able to provide 1,254 K-12 scholarships to Minnesota K-12 students, exceeding our goal of 1,000 student learning experiences with this project.

PROJECT RESULTS USE AND DISSEMINATION

The ongoing results of this project have been shared through our newsletters, our annual reports and social media accounts. Through these platforms, we have updated our constituents on the goals of the program, and the number of participants served. Some of our newsletters and annual reports are available online including: the Spring/Summer 2018 Newsletter, the Spring/Summer 2019 Newsletter, and the Fiscal Year 2019 Annual Report.

Project Completed: 6/30/2020 **FINAL REPORT**

Subd. 06 Aquatic and Terrestrial Invasive Species

Adapting Stream Barriers to Remove Common Carp

Subd. 06d $301,000 TF (FY2018)

Przemyslaw Bajer
U of MN - MAISRC
2003 Upper Buford Cir, 135 Skok Hall
St. Paul, MN 55108
Phone: (612) 625-6722
Email: bajer003@umn.edu

Appropriation Language
$301,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to conduct field tests at existing barrier sites and laboratory experiments to adapt a technology to remove common carp from streams during carp spawning migrations in Minnesota.

OVERALL PROJECT OUTCOME AND RESULTS

As a result of this project, we developed a new technology for managing the invasive common carp that is currently being commercialized by the University of Minnesota. The technology is easy to implement in various field conditions, requires minimum site engineering, and can be operated by a crew of two, which substantially reduces labor costs. This project started by testing whether the Whooshh system developed for migrating salmon might be adopted for common carp removal during spring migrations. Over the course of two field seasons we determined that the Whoosh technology is not easily adaptable for carp management because it requires that carp voluntarily swim into the Whooshh through a system of fish ladders, which proved problematic. However, we developed an alternative technology that appears to be effective and practical. Our technology is comprised of a low-voltage fish guidance system (available commercially) that guides the migrating carp into a large fenced in enclosure along the bank constructed using PVC pipes that slide into the stream bottom via horizontal support beams, a system of additional low-voltage electrodes placed inside the enclosure that can be activated as needed to crowd

the carp and then briefly immobilize them, and a system of partially-submersed conveyers that collect the immobilized carp and carry them on land. All elements of this technology were rigorously tested over two field seasons using over a 1,000 carp marked with electronic micro-tags. The entire system was then successfully tested in summer 2019 and spring 2020. The technology appears to be ready for management implementations. In addition to its applications for managing common carp throughout Minnesota, the technology we developed might be also applicable for managing other invasive fish, including the bighead and the silver carp that are advancing up the Mississippi and St. Croix rivers.

PROJECT RESULTS USE AND DISSEMINATION

The main results if a new technology for managing common carp described above. The technology is currently being commercialized by the University of Minnesota. In addition, our efforts to disseminate the results of this work include one manuscript published in peer-reviewed literature that described our early tests of the electric guidance system, another manuscript that describes the entire system and its performance during spring migrations of 2018 – 2020 that is currently in preparation, two TV interviews for local stations, three press articles including one in the New York Times, four regional or national conferences, four MAISRC presentations or publications.

Project Completed: 6/30/2020 **FINAL REPORT**

Tactical Invasive Plant Management Plan Development

Subd. 06e $296,000 TF (FY2018)

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
$296,000 the first year is from the trust fund to the commissioner of agriculture in cooperation with the Board of Regents of the University of Minnesota to develop regional priorities and an interagency action plan for invasive plant management to protect and promote habitat and native species. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

A Tactical Invasive Management Plan was developed for 14 species to improve the coordination and efficacy of managing these species at state and local levels. This plan offers guidance to decision-makers for prioritizing invasive plant management activities. It is recognized that there are insufficient financial and personnel resources to control all invasive plant populations in Minnesota. The aim was to provide information in the form of invasive plant distribution modeling, prioritization maps based upon multiple criteria, identification and management timing guides, and tools for reporting invasive plants and tracking management activities. Decisions about which invasive plant infestations are controlled are made at all levels from federal to local, but the majority of decisions are made at the local level. We made these tools available by integrating them into MDA's webpages for the selected species. The plan document is also available on the web and can be downloaded and printed.

Fourteen species were selected for assessment because they are designated noxious weeds in Minnesota and not considered early detection within the state but may be considered early detection at a regional or local level. The following species were selected: Canada thistle (Cirsium arvense), common/European buckthorn (Rhamnus cathartica), common tansy (Tanacetum vulgare), garlic mustard (Alliaria petiolata), glossy buckthorn (Frangula alnus), Japanese (Polygonum cuspidatum) and Bohemian (Polygonum × bohemicum) knotweeds, leafy spurge (Euphorbia esula), multiflora rose (Rosa multiflora), narrowleaf bittercress (Cardamine impatiens), plumeless thistle (Carduus acanthoides), purple loosestrife (Lythrum salicaria), spotted knapweed (Centaurea stoebe), and wild parsnip (Pastinaca sativa).

Training on this plan was provided to land managers. In person, regional workshops with a field tour were developed for this training scheduled for spring 2020. Sadly, the in-person workshops could not be held due to COVID 19. Instead, we developed an online course and held four, regional virtual workshops. The Tactical Invasive Management Plan online course was delivered to 146 individuals representing federal, state, county, municipal and tribal natural resource and agricultural agencies. Individuals also represented nonprofits, private companies, and academic institutions. The online course was approximately four hours in length and was organized into eight different online modules to facilitate learning. Five videos were recorded for the online course and are available as a YouTube playlist. The workshops were held on 06/09/20 for the southwest (25 participants), 06/10/20 for the northwest (47 participants), 06/11/20 for the southeast and greater metro (38 participants) and 06/11/20 for the northeast (25 participants).

PROJECT RESULTS USE AND DISSEMINATION

We presented on topics related to this Tactical Plan at 3 field workshops, 2 field tours, 3 conference booths, 9 Noxious Weed Advisory Committee meetings, 6 County Agricultural Inspector meetings, 14 Cooperative Weed Management Area meetings and gave 38 presentations to a wide range of audiences.

Training to use this plan was provided to land managers. In person, regional workshops with a field tour were developed for this training scheduled for spring 2020. Sadly, the in-person workshops could not be held due to COVID 19. Instead, we developed an online course and held four, regional virtual workshops (135 participants). The Tactical Invasive Management Plan online course was delivered to 146 individuals representing federal, state, county, municipal and tribal natural resource and agricultural agencies. Individuals also represented nonprofits, private companies, and academic institutions. The online course was approximately four hours in length and was organized into eight different online modules to facilitate learning. Five videos were recorded for the online course and are available as a YouTube playlist.

A peer-reviewed journal article highlighting the distribution modeling work has been published in the journal Scientific Reports. This paper describes the model distribution process and integrates it with future climate scenarios. The paper was led by Jason Reinhardt and co-authors.

Project dissemination will continue long after the project completion date. Materials developed for this project and the plan document are available on MDA's webpages. A draft of a peer-reviewed publication containing the multi-criteria decision results is complete and will be submitted. At the Upper Midwest Invasive Species Conference (11/02/20 – 11/06/20), an interactive poster on ISMTrack and a talk on the ISMTrack app will be presented. A presentation on the finalized Tactical Plan will be given to MDA's Noxious Weed Advisory Committee on 11/17/20.

Project Completed: 6/30/2020 **FINAL REPORT**

Maximize Value of Water Impoundments to Wildlife

Subd. 06f $195,000 TF (FY2018)

Alexandra Wardwell
Audubon Minnesota
1 Water St W, Ste 200
St. Paul, MN 55107
Phone: (218) 687-229 x11
Email: awardwell@audubon.org
Web: http://mn.audubon.org/

Appropriation Language
$195,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the National Audubon Society, Minnesota office, to control invasive hybrid cattails in water impoundments to improve habitat quality for migrating and breeding birds. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Agassiz Valley Impoundment, located near Warren, MN, is a 2,560-acre impoundment with a gated water storage area of 6,840 acre-feet that is managed by the Middle-Snake Tamarc-Rivers Watershed District (District). The primary purpose of this impoundment, like the many others across Minnesota, is for floodwater storage, however, they serve many other secondary functions including important wildlife habitat for migrating and breeding species. Due to their primary purpose, impoundments normally follow a hydrologic regime that includes water-level drawdown during the summer months to increase the impoundment's holding capacity for the fall and following spring. This draw down cycle can stimulate the germination of emergent wetland species, especially the non-native hybrid cattail that can form dense monocultures which crowd out native species and degrade habitat quality. Audubon Minnesota and the District collaborated on a project to test the effectiveness of a cattail management regime and the corresponding bird use throughout the treatment cycle. From 2017-2020, Audubon used a three-phase management approach that included conservative herbicide application, structural biomass reduction, and water management in an attempt to control and reduce the hybrid cattail population. Furthermore, Audubon acquired high-resolution orthophotography in 2019 and 2020 from drone flights to further delineate cattail populations and to allow for precise treatment. From 2017 to 2019, the normalized vegetation difference index decreased in 78% of vegetation points within the treatment area, indicating that the management regime was effective in areas that were able to be inundated. Avian response showed promising results; species diversity initially declined the first year following mechanical treatment (2018) but rebounded in 2019 and 2020 with respective increases of 27% and 41% when compared to the pre-treatment numbers in 2017.

This management regime shows promise as a long-term strategy to improve the habitat quality of impoundments across Minnesota while still allowing them to serve their primary purpose of flood mitigation. Hybrid cattail reduction in impoundments benefits the longevity of the impoundment, and thus, the surrounding Minnesotans depending on it for floodwater mitigation.

PROJECT RESULTS USE AND DISSEMINATION

Site documentation through photos occurred 2018-2020 during the growing season, especially concentrating on times with significant water level changes like spring flooding or coinciding with other management actions. A selection of those photos are included in the final report. Audubon Minnesota created a project webpage highlighting the work we are doing at the Agassiz Valley Impoundment. A

summer update on progress was posted to the project webpage mid-June E-news updates about the project went out to over 25,000 Audubon Minnesota e-newsletter subscribers over the course of the project.

We have also posted updates about the project to Audubon's social media platforms. Audubon has reached out to the Watershed District about adding a segment to the Agassiz Valley Impoundment Page about this project and they are open to it so we will continue to work on website additions to their webpage. Dissemination of the summary fact sheet on the project to area watershed districts is underway along with updates on the culmination of the project in our next e-newsletter and on social media. Our project webpage will also be updated with more photos and project summary information.

Recommendations and Ways to Improve Wildlife Habitat in Impoundments:

- A three-phased approach was most effective in treating and controlling hybrid cattail. The areas that experienced prolonged control were areas that could be inundated during prime cattail germination periods.
- Winter mowing was an effective method to reducing the standing dead cattail structure when fire is not an option.
- Follow up herbicide treatments are likely to be necessary if the area experiences a dry period during the growing season allowing hybrid cattail to germinate.
- Managing invasive non-native species and noxious weeds on the dikes through herbicide use or spot mowing allows delayed overall mowing or haying to occur to benefit ground nesting birds and reduce population sinks.
- Plan new impoundments with habitat management in mind.

Project Completed: 6/30/2020 **FINAL REPORT**

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

Promoting Conservation Biocontrol of Beneficial Insects

Research Project

Subd. 08b $400,000 TF (FY2018)

Vera Krischik
U of MN
1980 Folwell Ave, #219
St. Paul, MN 55108
Phone: (612) 625-7044
Email: krisc001@umn.edu
Web: http://www.entomology.umn.edu/cues

Appropriation Language
$400,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to research integrated pest management strategies, including insecticide alternatives, and overwintering habitat sites to conserve beneficial insects, including bees, butterflies, and predator insects. The integrated pest management strategies will be used to develop best management practices to increase pollinator and beneficial insect diversity and abundance in various restored habitats. This appropriation

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

OVERALL PROJECT OUTCOME AND RESULTS

Research investigated the best insecticides to conserve beneficial insects that can be used in green space. The new bee friendly insecticide chlorotraniliprole was highly toxic to butterflies and should not be used near butterfly habitat. Chlorotraniliprole did not kill bumblebees at 4 ppm, however Monarch butterfly larvae were killed at 0.2 ppm, while Painted lady butterfly larvae were killed at 0.03 ppm and adults were killed at 0.05 ppm chlorotraniliprole. This new and highly popular bee friendly insecticide is not butterfly friendly.

In contrast, the neonicotinoid insecticide chlothianidin that was commonly used as a seed treatment and foliar applied insecticide in agriculture, is highly toxic to bees, but not butterflies. Monarch butterfly larvae were killed at 4 ppm clothianidin, while Painted lady butterflies were killed at 96 ppm clothianidin, and adults were killed at 13 ppm clothianidin. At 20 ppb clothianidin bumblebees colonies had reduced nest weight and brood production. Bumblebees are more sensitive to the neonicotinoid clothianidin (40 ppb lethal dose, 20 ppb sublethal dose) compared to two species of butterfly (4, 96 ppm lethal dose).

Pesticide residue on wildflowers near potato fields showed that 100% of 36 samples tested contained at least 2 and up to 15 different pesticides. Research on pesticide residue on flowers near corn fields showed that of 40% of 32 samples tested contained only 1 pesticide and it was atrazine. Pesticide residue was highest on wildflowers near potatoes and demonstrates the need for buffer strips.

Beetle banks are 4 ft piles of mulch that were created at 3 park sites in Washington County. At a citizen science field day, beetle banks were found to a mean of 131 insects compared to control plots with 1 insect. Research on reed nests as habitat for native stem nesting bees showed that there were 236 occupied reeds or 95% of the nests were occupied. Both beetle banks and stem nests increased insect abundance and are cultural methods to increase insect numbers.

PROJECT RESULTS USE AND DISSEMINATION

The grant produced 8 new outreach bulletins, 1 new poster, and research results which are presented at a new website. These outreach bulletins are attached to the work plan.

Our lab has provided 4 workshops per year and 28 talks per year to professionals and consumers on issues related to the grant's research. The bulletins, poster, and research summaries were handed out at outreach events. After 2020 we will continue to use these bulletins at outreach events to educate consumers on IPM programs to protect bees, butterflies, and beneficial insects, such as the parasitoids of the emerald ash borer.

Project Completed: 6/30/2020 **FINAL REPORT**

Subd. 09 Land Acquisition, Habitat and Recreation

Minnesota State Parks and State Trails Land Acquisition

Subd. 09c $1,500,000 TF (FY2018)

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
$1,500,000 the first year is from the trust fund to the commissioner of natural resources to acquire approximately 373 acres from willing sellers for authorized state trails and critical parcels within the statutory boundaries of state parks. State park land acquired with this appropriation must be sufficiently improved to meet at least minimum management standards, as determined by the commissioner of natural resources. A list of proposed acquisitions must be provided as part of the required work plan. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota Environment and Natural Resources Trust Fund funding resulted in the Department of Natural Resources acquiring approximately 373 acres of land within the statutory boundaries of four Minnesota State Parks.

- Acquired 80 acres in Maplewood State Park. This acquisition is located within the southeast portion of the state park, which contains a large contiguous tract of maple basswood hardwood forest over a rolling topography. This forest is similar to what is known to exist at the time of European settlement of the area. This undisturbed/undeveloped forest is important nesting habitat for neo-tropical forest songbirds.
- Acquired 153 acres in Sibley State Park. This property affords park visitors approaching along TH71 a glimpse of Minnesota's original prairie landscape with rolling grasslands and wetlands. Recreational trail users on this parcel will have views of the transitions from prairie to savanna to woodlands. This parcel will also provide a route for the Glacial Lakes State Trail connection to Sibley State Park.
- Acquired 30 acres in Minneopa State Park. This acquisition helps in protecting cultural resources, provide for sustainable wildlife habitat and new hiking, bird watching and facilitate interpretive programming opportunities. It is located adjacent to existing DNR ownership along the Minnesota River which will connect ~164 acres of publically owned, DNR managed land, and contributes to the consolidated management efforts to maintain and restore native vegetation as well as buffer for Minnesota River and protection of river watershed.
- Acquired 158 acres in Frontenac State Park. This land improves the park's ability to preserve and buffer natural resources, wildlife habitat and view sheds. This parcel also has a stunning overlook and incredible birding opportunities for unique trail hiking experiences.

PROJECT RESULTS USE AND DISSEMINATION

Maplewood and Sibley acquisitions dissemination have been communicated through updated state park maps reflecting state managed land and are identified as public land open to be used and enjoyed by all visitors. Now, that an acquisition consultant has been appointed, dissemination will continue for the rest of the acquired parcels.

Project Completed: 06/30/2020 **FINAL REPORT**

Minnesota State Trails Acquisition, Development and Enhancement

Subd. 09d $1,038,000 TF (FY2017 - $999,000 / FY2018 - $39,000)

Kent Skaar
MN DNR, Division of Parks and Trails
500 Lafayette Rd, Box 25
St. Paul, MN 55155
Phone: (651) 259-5636
Email: Kent.skaar@state.mn.us
Web: http://www.mndnr.gov

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

Project due to be completed: 06/30/2020 **Work Plan**

Leech Lake Acquisition

Subd. 09f $1,500,000 TF (FY2018)

Joseph Fowler
Leech Lake Division of Resource Management
190 Sail Star Dr NE
Cass Lake, MN 56633
Phone: (218) 335-7400
Email: Joe.fowler@llojibwe.org
Web: http://www.llojibwe.org/drm/index.html

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

Project due to be completed: 08/30/2019 **Work Plan**

Land Acquisition for Voyageurs National Park Crane Lake Visitors Center

Subd. 09i $950,000 TF (FY2018)

Jim Janssen
Town of Crane Lake
PO Box 402
Crane Lake, MN 55725
Phone: (218) 993-1303

Email: info@cranelaketwp.com
Web: http://www.cranelaketwp.com

Appropriation Language
$950,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the town of Crane Lake, in partnership with Voyageurs National Park and the Department of Natural Resources, to acquire approximately 30 acres to be used for a visitor center and campground. Income generated by the campground may be used to support the facility.

OVERALL PROJECT OUTCOME AND RESULTS

The Township of Crane Lake received a $950,000 grant from the ENRTF to acquire an approximately 30 acre former resort site on the shores of Crane Lake to work in partnership with an adjacent DNR 7 acre site to build an entrance point to Voyageurs National Park that will include a National Park Service Visitors Center, boat ramp, docks, beach, campground, restrooms, and educational and community space. The Township of Crane Lake has purchased the property and will be working with their partners to begin the design and development phases of their development. The total cost of the parcel was $982,000 with $950,000 coming from the ENRTF and the Township providing $32,000 in their own funds.

PROJECT RESULTS USE AND DISSEMINATION

During the process of planning, land sale negotiations, and securing the former Borderland Resort site, the Township of Crane Lake has been posting progress on their website, updating local newspapers, working with local tourism offices, area chambers of commerce and working very closely with their partners including the DNR and Park Service. The Township will continue to disseminate information through the same media through the planning, design and construction phases of the overall development.

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 10 Administration

Contract Agreement Reimbursement

Subd. 10a $135,000 TF (FY2018)

Katherine Sherman-Hoehn
MN DNR
500 Lafayette Rd, Box 10
St. Paul, MN 55155
Phone: (651) 259-5533
Email: Katherine.Sherman-Hoehn@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$135,000 the first year is from the trust fund to the commissioner of natural resources, at the direction of the Legislative-Citizen Commission on Minnesota Resources, for expenses incurred for contract agreement reimbursement for the agreements specified in this section. The commissioner shall provide documentation to the Legislative-Citizen Commission on Minnesota Resources on the expenditure of these funds.

OVERALL PROJECT OUTCOME AND RESULTS

This appropriation was used to support the ENRTF contract management program, which ensured that ENRTF grantees expended grant funds in compliance with state law, session law, approved work plans, and Office of Grants Management grants policies.

The DNR Grants Unit managed 67 grants active in FY 2017. In FY 2018, the Grants Unit managed 71 active grants. Between 7/1/2016 when the services began and 06/30/2018 when they ended, the DNR Grants Unit:

- Made 359 reimbursements to grantees totaling $13,053,825.58
- Prepared and executed 21 ML 2017 grant agreements
- Published 6 editions of the quarterly newsletter for all grantees
- Billed 350 hours at the FY 2017 professional services rate of $63.00/hr
- Billed 1,534 hours at the FY 2018 professional services rate of $63.00/hr
- Monitored all grants in compliance with Office of Grants Management policies.

PROJECT RESULTS USE AND DISSEMINATION

Project personnel were in frequent contact with appropriation recipients and LCCMR staff. Information was disseminated through manuals, training sessions, orientations, meetings, memos, letters, emails, newsletter, and phone.

Project Completed: 06/30/2019 **FINAL REPORT**

1. **M.L. 2016 Projects Completed**
   January 15, 2019 – January 15, 2021

   MN Laws 2016, Chapter 186, Section 2

M.L. 2016 Projects

MN Laws 2016, Chapter 186, Section 2 (beginning July 1, 2016)

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

Subd. 03 Foundational Natural Resource Data and Information

Data-Driven Pollinator Conservation Strategies

Research Project

Subd. 03a $520,000 TF

Daniel Cariveau
U of MN
1980 Folwell Ave
Falcon Heights,MN 55108
Phone: (970) 391-0783
Email: dcarivea@umn.edu
Web: http://www.dancariveau.com

Appropriation Language
$520,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to improve understanding of the relationships and interactions between native bee pollinators and rare and declining plant species and to determine optimal placement and species plantings for pollinator habitat in order to develop guidelines for planning, designing, and planting pollinator habitat. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Tallgrass prairie in Minnesota has declined by over 98%. A critical tool for prairie conservation is ecological restoration. One goal of prairie restoration is to conserve, protect and restore native bees and the pollination services they provide. In Minnesota, there are over 450 species of bees with the prairies having the highest diversity and abundance. However, there is a lack of information available to enable land managers to effectively create and maintain restorations for bees. This project addresses three objectives. First, we test how surrounding landscape influences native bee communities in prairie restorations. This information can help land managers determine where to place restorations and which restorations to prioritize for management. Second, we examined how plant communities influence bee communities. Third, we studied pollination in restorations and evaluated which bee species were the most effective pollinators. We sampled bees at 26 sites in the summers of 2017 - 2019. We collected over 18,000 bee specimens and recorded over 11,000 bee by plant interactions. We found that surrounding landscape had less of an impact on bee communities than local flower communities. This suggests that increasing plant diversity is a critical tool for enhancing bee communities while exact placement is less important. We also found that restorations and remnants have unique bee and flower communities. This suggests that we might not be meeting restoration goals as bee communities in quite different than remnant prairies. Finally, we found large variation in the pollination effectiveness among bee groups. This research benefits Minnesotans highlights the importance of maintaining diverse plant communities in restorations. As surrounding landscape did not influence bee communities or pollination, restorations in areas of high agriculture can be effective. We have created a highly resolved

open-access dataset for future studies. We have published five peer-reviewed manuscripts to date and are attached as supplementary material.

PROJECT RESULTS USE AND DISSEMINATION

We have disseminated our results to the scientific community as well as the general public. We gave 6 presentations at national conferences. Two of these were invited presentations. Dan Cariveau also presented these results at three departmental seminars at other universities. We have published a total of 5 peer-reviewed manuscripts. We expect at least three more. Ian Lane will be submitting the second chapter of his dissertation in early 2021 and third chapter before May 2021. At which point he will defend his PhD thesis. Dr. Gabriella Pardee is finishing up a manuscript on pollen efficiency of prairie plants. In addition to publishing in journals, we have also made the data and code available and open access. All published work and presentations have and will continue to acknowledge this ENRTF support. We have also presented the results of this research at outreach events. Ian Lane has also been a guest on the Minnesota Department of Natural Resources Prairie Pod podcast. This podcast is focused on the science of prairie conservation. We led a highly successful field day on pollinators in prairies. This was co-led by Ian Lane and Dan Cariveau. In addition, we partnered with the United States Fish and Wildlife Service, Minnesota Department of Natural Resources and the Prairie Reconstruction Initiative. This brought in 50 natural resource professionals and was focused on prairie sites in southwestern Minnesota. Finally, this funding has supported two graduate students. Alan Ritchie defended his master's thesis in December 2019. He is now the Pollinator Coordinator for the Minnesota Department of Natural Resources. Ian Lane is finishing his PhD thesis. He has scheduled a defense date for May 2021.

All manuscripts with data and analyses have open-access data and code. These data can be found on the Digital Repository for the University of Minnesota. There have been 99 downloads of these data as of December 22, 2020. Publications as of December 2020 are included in Emerging Topics in Life Sciences, Journal of Applied Ecology, The Great Lakes Entomologist, and Restoration Ecology.

Project Completed: 06/30/2019 **FINAL REPORT**

Native Bee Surveys in Minnesota Prairie and Forest Habitats

Subd. 03b $600,000 TF

Jessica Petersen
MN DNR
500 Lafayette Rd
St. Paul, MN 55155
Phone: (651) 259-5130
Email: jessica.d.petersen@state.mn.us
Web: www.dnr.state.mn.us/pollinators

Appropriation Language
$600,000 the second year is from the trust fund to the commissioner of natural resources to continue to assess the current status and distribution of native bee pollinators in Minnesota by expanding surveys into the prairie-forest border region and facilitating interagency collaboration and public outreach on pollinators. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Wild bees provide vital ecosystems services including pollination, thus working to sustain resilient ecosystem functioning. Without baseline information about the diversity and distribution of bees in

Minnesota, we lack the ability to provide efficient and effective conservation actions to protect bees and their habitats. We addressed these knowledge gaps by surveying natural areas in the Prairie Parkland, Tallgrass Aspen Parklands, and Eastern Broadleaf Forest ecological provinces. Since 2016, we surveyed bees using bowl traps at 70 sites and hand netting bees from flowers at 93 sites across 38 counties. Bowl trap methods were used to survey bees every three weeks during the season, for a total of up to eight survey rounds each year. These survey efforts resulted in nearly 23,000 bee specimens collected across the two methods. Several new state records were added to the list for a total of 470 species, up from 432 at the beginning of the project. Our survey efforts have yielded countless county-level records for many species, thus gaining valuable knowledge about the distribution of bees in Minnesota. These specimens are continually being accessioned into the permanent repository at the University of Minnesota Insect Collection. Additionally, we trained a total of 35 individuals during partnered workshops held in collaboration between the MNDNR and the U of M Bee Lab to identify wild bees of Minnesota. Staff also participated in countless outreach events, promoting bees and other pollinators to Minnesotans.

PROJECT RESULTS USE AND DISSEMINATION

We have conducted countless outreach presentations to the public about bees in Minnesota. Likewise, we continue to update and maintain the various MNDNR pollinator-related websites. Specifically related to an update on the wild bee survey, we created a short two-page handout that summarizes the findings to date. These outreach and education efforts have provided easily-accessible information and facilitated communication concerning Minnesota's pollinators amongst researchers.

Project Completed: 06/30/2019 **FINAL REPORT**

Prairie Butterfly Conservation, Research, and Breeding - Phase II

Research Project

Subd. 03c $750,000 TF

Subd. 03c1 - $421,000 TF

Erik Runquist
Minnesota Zoological Garden
13000 Zoo Blvd
Apple Valley, MN 55124
Phone: (952) 431-9200
Email: erik.runquist@state.mn.us
Web: http://www.mnzoo.org

Subd. 03c2 - $329,000 TF

Robert Dana
MN DNR
500 Lafayette Rd
St. Paul, MN 55155
Phone: (952) 431-9200
Email: robert.dana@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$750,000 the second year is from the trust fund. Of this amount, $421,000 is to the Minnesota

Zoological Garden and $329,000 is to the commissioner of natural resources in collaboration with the United States Fish and Wildlife Service to continue efforts to prevent the extinction of imperiled native Minnesota butterfly species through breeding, research, field surveys, and potential reintroduction. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

ML2016 03c:

- *03c1: Prairie Butterfly Conservation, Research, and Breeding - Phase II* - $421,000
- *03c2: Prairie Butterfly Conservation, Research, and Breeding - Phase II* - $329,000

Subd. 03c1: Prairie Butterfly Conservation, Research, and Breeding - Phase II - $421,000 TF

Erik Runquist
Minnesota Zoological Garden
13000 Zoo Blvd
Apple Valley, MN 55124
Phone: (952) 431-9200
Email: erik.runquist@state.mn.us
Web: http://www.mnzoo.org

OVERALL PROJECT OUTCOME AND RESULTS

The Prairie Butterfly Conservation Program at the Minnesota Zoo has grown substantially during this project, and we have accomplished all Outcomes. We operate the only conservation rearing programs for two endangered butterflies in the United States. We launched the first Dakota skipper reintroduction program, rearing and releasing ~930 Dakota skippers at the Hole-in-the-Mountain Prairie Preserve near Lake Benton. , and reared thousands more. We are reinforcing one of the last populations of the Critically Endangered Poweshiek skipperling, the first of its kind in the US, releasing the two adults in 2018 and 14 more in 2019. We are also improving husbandry practices with the Minnesota Threatened garita skipperling. We currently hold thousands more of these three butterflies to continue the insurance, reintroduction, reinforcement, and research programs, supported in part by a new ENRTF appropriation.

We have improved our understanding of threats to wild populations and of conditions needed to sustain and re-establish healthy populations. We have contributed to a key research need by beginning to link the quantities of pesticides found on prairie grasses that the protected skippers feed on in the wild with experimental testing of the toxicity effects of those quantities on skipper caterpillars. Significant additional research is needed in this area to fully understand the scope of the risk, particularly from pesticides that we have commonly observed in the wild but have not yet tested.

The Minnesota Zoo has received significant attention through media interviews and invited speaking engagements. We have created and established a great deal, and many agencies and organizations seek our advice as experts, but recovery of these endangered butterflies can only be fully achieved through partnerships. Successful conservation of these butterflies and the prairies they depend upon will have broad benefits to a wide range of wildlife and Minnesotans.

PROJECT RESULTS USE AND DISSEMINATION

Our work has garnered attention and the Minnesota Zoo has become a key agency in the international conservation programs for Poweshiek skipperling and Dakota skipper. We remain active in multiple

planning processes and multi-party action teams for both species and have hosted multiple workshops and meetings, including the 2019 meeting for the International Poweshiek Skipperling Conservation Partnership. Similarly, the field component of the Skipper Identification Workshop of this joint Zoo-DNR ENRTF appropriation (Activity 4; to be discussed in greater detail in the Update provided by DNR) was held in late June 2019 at the Hole-in-the-Mountain Prairie Preserve at the site of the Dakota skipper reintroduction program as well as several other sites in southwest Minnesota.

Across the duration of this project, there have been five TV stories, two radio segments, three newspaper articles, two major blog posts, dozens of social media posts, and dozens of speaking engagements. The Dakota skipper reintroduction effort has recently been the subject of TV segments (including two live) and a newspaper story that was widely shared across other news outlets across Minnesota and the Northern Plains, including Public TV's Prairie Sportsman, Pioneer Press, KSFY-TV, (Sioux Falls, SD), and KARE11-TV, (Minneapolis, MN). The research generated by this Project will be submitted for publication a peer-reviewed scientific journals.

Subd. 03c1 Completed: 06/30/2020 **FINAL REPORT**

Subd. 03c2: Prairie Butterfly Conservation, Research, and Breeding - Phase II - $329,000 TF

Robert Dana
MN DNR
500 Lafayette Rd
St. Paul, MN 55155
Phone: (952) 431-9200
Email: robert.dana@state.mn.us
Web: http://www.dnr.state.mn.us

OVERALL PROJECT OUTCOME AND RESULTS

Butterflies are in trouble in western Minnesota prairies. Ten species are of statewide conservation concern and two species are federally listed. Knowing where these species persist on the landscape is important to their conservation. Likewise, understanding the factors that affect population size is important to the conservation of existing populations. The skipper butterflies are difficult for untrained individuals to identify with certainty. The lack of qualified surveyors limits the ability of biologists and managers to search for skippers.

Seven of the 13 species were not found across all sites surveyed. All of these missing butterflies are skippers. We monitored populations of Dakota skipper and Pawnee skipper in response to prairie management. Conservation grazing, or perhaps the lack of fire, appears to be beneficial to persistence of Pawnee skipper. The results of Dakota skipper monitoring are less clear and will require additional years of monitoring. Dakota skippers at the reintroduction site appear highly localized to within a few hundred meters of the point of release. This is perhaps due to low dispersal ability, mortality, and/or lower detection ability with increasing radius from the release point. The MNDNR, MN Zoo, and USFWS partnered to successfully train at least 30 individuals to identify imperiled skippers, thus increasing the statewide capacity for monitoring greatly. All of these actions work to make more informed, science-based decisions about the conservation of rare butterflies for all Minnesotans to enjoy.

PROJECT RESULTS USE AND DISSEMINATION

During this project, the USFWS consulted project staff in drafting the recovery plans for both federally listed species, the Dakota skipper and the Poweshiek skipperling. Information gained from the surveys conducted through this project were essential in writing the recovery plans. These draft recovery plans were then disseminated for public comment and review.

The project manager in collaboration with the MN Zoo and USFWS developed species identification cards for the imperiled skipper species and their look-a-likes as part of the training sessions. These cards are specific to western Minnesota skippers and are an important tool in the continued survey and conservation of these rare skippers. We continue to receive complements and requests for these identification cards.

Subd. 03c2 Completed: 06/30/2020 **FINAL REPORT**

Statewide Monitoring Network for Changing Habitats in Minnesota

Subd. 03d $500,000 TF

Hannah Texler
MN DNR
500 Lafayette Rd, Box 25
St. Paul, MN 55155
Phone: (651) 259-5048
Email: hannah.texler@state.mn.us
Web: https://www.dnr.state.mn.us/mbs/ecologicalmonitoring/index.html

Appropriation Language
$500,000 the second year is from the trust fund to the commissioner of natural resources to develop a consolidated statewide network of permanent habitat monitoring sites in prairies, forests, and wetlands to help guide and prioritize habitat protection and management decisions in response to environmental change. The design and testing methodologies of monitoring plots must address the status of pollinators and pollination. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This project developed a network for monitoring change in the condition of prairies, forests, and wetlands across Minnesota to inform land protection and management in the face of rapid environmental change. The first activity was the development of long-term monitoring plots for the newly established Ecological Monitoring Network (EMN). We established 125 permanently marked plots on public and private lands, and collected data on native vegetation, soils, and other aspects of the environment. To address pollinators in monitoring plots, bee specialists visited six plots and hand-netted over 75 bees. The 125 plots represented a broad spectrum of quality. We recorded 885 vascular plant species, which represents 44% of the total number of species in Minnesota. The plot with the highest diversity was a tamarack swamp with 112 species. Over half (52%) of the plots contained at least one non-native plant species. Upland and wetland prairies were the plant communities with the most non-native species. In future years, we plan to install another 475 plots, and then to resample all plots every 6 years. Data analyses will include summaries of how native prairies, forests, and wetlands change over time, and how those changes are related to habitat patch size, past management, and other factors.

This project also included historic vegetation sampling to measure past changes in native vegetation by using relevé vegetation plots originally sampled 20-40 years ago. We sampled 80 relevés in prairies and forests in State Parks and Scientific and Natural Areas in east-central Minnesota, and sampled the first eight of 80 relevés to be sampled in 2019 on the North Shore of Lake Superior. We began analyses of the 80 relevé plots from southeastern and east-central Minnesota. Results indicate that we can detect significant changes in vegetation using the relevé resampling technique. For example, we found that

prairies that have had fire management had fewer non-native invasive species, less cover by vines, and higher native species diversity than those that have not had fire management. However, we did detect increasing frequency of non-native invasive species such as smooth brome and common buckthorn, as well as increasing frequency of native vines, over time on all plots. Further analyses will be completed and the results disseminated in 2020.

PROJECT RESULTS USE AND DISSEMINATION

A web page for this project was created and can be accessed here: https://www.dnr.state.mn.us/mbs/ecologicalmonitoring/index.html. The project goals, objectives, most recent brochure, and field methods, including a link to the Standard Operating Procedures (DNR Biological Report Number 121), can be found on this web site.

Reports summarizing data collected in each plot were sent to the respective landowner or land manager for that plot following each field season.

Email updates regarding the project's progress were shared with DNR Oversight and Project Teams following 2017 and 2018 field seasons.

PowerPoint presentations were developed and presented at a number of venues, including the Minnesota Biological Survey annual meeting, the Minnesota Native Plant Society, The Nature Conservancy, and the University of Minnesota's Conservation Science Symposium.

Project Completed: 06/30/2019 **FINAL REPORT**

Completing National Wetland Inventory Update for Minnesota

Subd. 03e $1,500,000 TF

Steve Kloiber
MN DNR
500 Lafayette Rd
St. Paul, MN 55155
Phone: (651) 259-5164
Email: steve.kloiber@state.mn.us
Web: http://www.dnr.state.mn/eco/wetlands/nwi_proj.html

Appropriation Language
$1,500,000 the second year is from the trust fund to the commissioner of natural resources to complete the update and enhancement of wetland inventory maps for counties in central and northwestern Minnesota. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The National Wetlands Inventory (NWI) update project was a collaborative effort lead by the Minnesota DNR that:

- Developed new methods for integrating lidar data into wetland mapping,
- Created of a suite of lidar-derived topographic datasets to assist with wetland mapping,
- Acquired new statewide, high-resolution spring leaf-off aerial imagery,
- Completely re-mapped and classified all wetlands larger than 0.5-acre in size,

- Engaged stakeholders in the development and review of the updated data,
- Enhanced the NWI with additional attributes, and
- Efficiently delivered data to various user groups through multiple means.

These data replace the original 1980s NWI data. In this final phase of the overall effort, we updated wetland inventory maps for the remaining 20,700 square miles of northwestern Minnesota covering 19 counties. All the wetland data from each project phase has been edge-matched to create a single statewide wetland inventory containing nearly 2.4 million wetland polygons.

Quality assurance of the data included visual inspection, automated checks for attribute validity and consistency, as well as a formal accuracy assessment based on independent field data. The updated NWI data have a 95% user accuracy for wetland identification. Further details on the methods employed can be found in the technical procedures document for this project located on the DNR wetland-mapping website.

PROJECT RESULTS USE AND DISSEMINATION

Wetland map data developed by this project are freely available through web-based data distribution hubs and online viewing through web mapping applications including the Minnesota Geospatial Commons and the DNR Wetland Finder. The final statewide updated data were posted to these distribution points on May 31, 2019.

The DNR issued a press release on June 3, 2019 announcing the availability of the statewide NWI. The DNR also included social media posts regarding this release. The story was picked up by several media outlets. The DNR developed a web application to support ongoing stewardship of the NWI data. The web application provides a simple and consistent method for state and local wetland professionals to submit change requests to the DNR. DNR plans to incorporate these user requests into annual updates of the NWI.

The DNR also developed a NWI User Guide and Summary Statistics. This guide provides a brief overview of the potential uses, limitations, access and technical aspects of the Minnesota Wetland Inventory. This guide also provides summary statistics of wetland types by county and major watershed. Printed copies are being distributed to local Soil and Water Conservation Districts, BWSR wetland specialists, DNR area hydrologists, and others. In addition, the DNR developed and printed 1000 copies of a map poster. These are being sent to a broad array of potential users of the NWI including SWCDs and local government units.

Project Completed: 06/30/2019 **FINAL REPORT**

An Updated and Enhanced National Wetland Inventory for Minnesota
Technical Procedures for Updating the National Wetlands Inventory of Northwest Minnesota
Press Media
Minnesota Wetland Inventory: Wetland Functional Assessment Final Report and Guidance Handbook
User Guide and Summary Statistics

Assessment Tool for Understanding Vegetation Growth Impacts on Groundwater Recharge

Subd. 03f $212,000 TF

Gene-Hua Ng (Crystal)
U of MN

310 Pillsbury Dr SE
Minneapolis, MN 55455
Phone: (612) 624-9243
Email: gcng@umn.edu

Appropriation Language

$212,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a statewide assessment tool to help understand the relationship between vegetation growth and impacts on groundwater recharge under changing land use and climate. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This project investigated the impact of varying plant growth on groundwater recharge using an ecohydrological computer model, the Community Land Model (CLM). With the model, we simulated recharge for two different vegetation conditions – one in which actual, year-to-year varying vegetation conditions were included, and the other (the standard approach) in which the average 16-year vegetation conditions were included. The study was carried out for 2000-2015 at a resolution of 25km for the entire state of Minnesota. The overall statewide average recharge for the 16-year period was 2.9 inches per year with varying vegetation and 2.8 inches per year with repeated, 16-year average vegetation. Although the difference between these results is very small, it is more variable on an annual and local scale and can differ up to 28% for certain times and locations. The impact on recharge due to the vegetation also varies by ecoregions. Recharge in the North Central Hardwood Forests (NCHF) is the most sensitive to varying vegetation, and the North Lake and Forests (NLF) in northeastern Minnesota (consisting primarily of coniferous forests) is the least sensitive. Across the state, we also found that most year-to-year variations in vegetation occur mostly due to temperature rather than precipitation, with the greatest temperature sensitivities in the Great Plains (GP) in the western Minnesota. With overall increasing and more variable temperatures projected for the future, accounting for dynamic responses in vegetation becomes even more important for accurately predicting changes in recharge, especially in sensitive areas of the state like western and central Minnesota. Through our study, we also found that southeastern and northeastern Minnesota suffer from sparser and lower quality groundwater level data compared to other parts of the state, serving as a major limitation in accurate recharge assessments there. Expanding groundwater monitoring in these areas will be important for managing and preparing for future impacts of climate and plant variability on recharge in these areas.

PROJECT RESULTS USE AND DISSEMINATION

The methodology and main results will be documented on the project website. Poster and oral presentations were made in multiple national and regional conferences, workshops, and seminars including: American Geophysical Union Fall Meeting (2017, 2018 and 2019), Community Earth System Model workshop, Colorado (2019), Earth and Environmental Sciences Student Research Symposium, Minnesota (2018), and Water Resource Symposium, Minnesota (2017).

Source code modifications for the ecohydrological CLM model and the Ensemble Kalman Filter (EnKF) calibration code have been publicly shared online via a GitHub code repository. An error in the source code of the ecohydrological CLM model – a model used by a large number of users globally - was discovered and fixed. We will be submitting the fix officially for the public review so that it can be included in future versions of the model. We filtered and removed erroneous observations for multiple wells in the Cooperative Groundwater Management (CGM) Database. We have communicated these issues to MN-DNR in order to help them improve this public dataset. Additionally, we are preparing a scientific journal article to share our findings with the academic community.

Project Completed: 06/30/2019 **FINAL REPORT**

Sentinel Lakes Monitoring and Data Synthesis - Phase III

Subd. 03g $401,000 TF

Melissa Treml
MN DNR
500 Lafayette Rd
St. Paul, MN 556601
Phone: (651) 259-5231
Email: melissa.treml@state.mn.us
Web: http://www.dnr.state.mn.us/fisheries/management/research.html

Appropriation Language
$401,000 the second year is from the trust fund to the commissioner of natural resources for the third and final phase of a monitoring and multidisciplinary research effort on 25 sentinel lakes in Minnesota, which will integrate and synthesize previously collected data to enhance understanding of how lakes respond to large-scale environmental stressors and provide for improved ability to predict and respond to lake changes for water and fisheries management. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

We are grateful for the ENRTF's support, which has been instrumental for the development and success of the Sentinel Lakes Program. DNR and PCA have ensured the continuation of the program including DNR fisheries support for 3 permanent Sentinel Lakes staff positions who will direct program activities and lead remote monitoring and pelagic and juvenile fish sampling, area fisheries staff and IBI Program support through continued fish sampling and remote monitoring and PCA and EWR support through continued water quality, zooplankton, macroinvertebrate and aquatic plant collection and analysis. These monitoring activities will foster the continuation of the long-term monitoring framework and help collaborators utilize the existing framework to investigate specific questions.

Phase 3 of the Sentinel Lakes Long-Term Monitoring Program comprised a wide variety of data management, monitoring and research activities on the 25 Sentinel Lakes. During 2016-2019, Highlights include:

- The Sentinel Lakes datasets have been gathered, assembled, standardized, undergone QA/QC, and metadata have been created for each dataset with all data and metadata available upon request.
- We have outfitted all 25 Sentinel Lakes with continuous water temperature loggers for a total of 180 currently active recording loggers.
- We have summarized and analyzed trends in water quality, water temperature, water level, zooplankton, pelagic fish and game fish trends over time.
- We have established new sampling activities targeting juvenile fish with an emphasis on growth, and new aging protocols for pelagic fish to better track year class strength, growth, and mortality.
- We have identified dissolved oxygen monitoring as a data gap and we have already made progress to fill this gap.

- We have prioritized the dissemination of Sentinel Lakes data and information which has resulted in an updated public website (https://www.dnr.state.mn.us/fisheries/slice/index.html), data sharing with numerous collaborators, 30+ presentations, public media coverage, and research proposals and funded projects with collaborators.

PROJECT RESULTS USE AND DISSEMINATION

We have prioritized the dissemination of Sentinel Lakes data and information over the last 3 years which has resulted in an updated public website (https://www.dnr.state.mn.us/fisheries/slice/index.html), data sharing with numerous collaborators, 30+ presentations, public media coverage, and research proposals and funded projects with collaborators. Specifics are provided in the date specific updates with highlights below.

The updated Sentinel Lakes section of the DNR website includes new information and a smart phone friendly design. In addition to the program description and contacts list we have also included detailed lake descriptions, methodology, and updated research project descriptions.

The Sentinel Lakes datasets have been gathered, assembled, standardized, undergone QA/QC, and metadata have been created for each dataset with all data and metadata available upon request. We are working with MNiT staff to ensure compatibility with existing DNR database architecture, branding and ADA requirements. Details located under Activity 1 Outcome 1.

We have fostered a data sharing philosophy that has encouraged outside researchers to request Sentinel Lakes data. Now that data are reviewed for QA/QC and metadata have been created, data requests can be filled quickly and are complemented by trophic level specific metadata. As noted, data sharing is an important part of the Sentinel Lakes Program and one that we will continue to promote. In the past 3 years we have shared data with collaborators who include: Universities (University of Minnesota Twin Cities, University of Minnesota Duluth and Large Lakes Observatory, Bemidji State University, University of North Carolina, Kalamazoo College), Federal scientists (Environmental Protection Agency, USGS, USFWS, NPS), Tribal Biologists (1834 Treaty Authority, Lac du Flambeau Band of Lake Superior Chippewa Indians, Red Lake Department of Natural Resources), state agencies (Wisconsin DNR, MN PCA, and MN DNR) and private industry (TetraTech).

Data sharing has resulted in numerous submitted research proposals including several funded grants and projects including $46,500 from Midwest Glacial Lakes Fish Habitat Partnership to support dissolved oxygen monitoring, 2 funded Sport Fish Restoration projects lead by DNR, and LCCMR support for Kathryn Schreiner (UMD and Large Lakes Observatory) and colleagues for the project “A Survey of Microplastics in Minnesota’s Inland Aquatic Food Webs”.

We have given 30+ presentations to groups like The Association for the Sciences of Limnology and Oceanography; Midwest Fish and Wildlife Conference; Annual Meeting of the Minnesota Chapter of the American Fisheries Society; Bemidji State University; the Fish and Wildlife Division’s Climate and Renewable Energy Steering Team; Section, Region, and Unit specific DNR meetings; Interagency research meeting with the Minnesota Department of Agriculture; Board of Water and Soil Resources; Minnesota Pollution Control Agency; University of Minnesota; the St. Croix Watershed Research Station; and the Department of Natural Resources. Also several webinars were given to EPA’s regional lake monitoring network and we presented and instructed participants at the Remote Sensing Workshop.

Several public media outlets have featured Sentinel Lakes stories including Minnesota Public Radio, The Star Tribune, The Echo Press, and the Outdoor News.

Manuscript “Stable isotopes indicate that zebra mussels increase dependence of lake food webs on littoral energy sources” by Brian Herwig and colleagues was published in 2018 in the journal of

Freshwater Biology documenting energy flow change pre and post zebra mussels infestation in Lake Carlos.

The Second Sentinel Lakes Summit brought 70 collaborators from DNR, PCA, university faculty and federal researchers together to learn, discuss, and advance the science related to long term monitoring and changes in Minnesota lakes.

Project Completed: 06/30/2019 **FINAL REPORT**

Stable isotopes indicate that zebra mussels *(Dreissena polymorpha)* increase dependence of lake food webs on littoral energy sources

---

State Spring Inventory for Resource Management and Protection - Phase II

Subd. 03h $370,000 TF

Jim Berg
MN DNR
500 Lafayette Rd
St. Paul, MN 55155
Phone: (651) 259-5680
Email: jim.berg@state.mn.us
Web: https://www.dnr.state.mn.us/

Appropriation Language
$370,000 the second year is from the trust fund to the commissioner of natural resources to continue a systematic inventory of springs statewide to provide fundamental data needed to maintain spring flows and protect groundwater-dependent resources. Increased outreach to the public and other entities must be conducted to assist in the identification, documentation, and publication of spring locations. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS
Springs are natural points of groundwater discharge. Springs provide flow for:

- coldwater (trout streams) and cool water fisheries;
- base flow in streams during dry periods;
- create and sustain unique ecological habitats; and
- maintain the integrity of aquatic systems against invasive species.

Sustainable management of natural resources requires easily accessible location and feature characteristics data. Natural resources cannot be managed and conserved if we don't know where they are.

A permanent, web accessible map and comprehensive, easy to use database (Minnesota Spring Inventory, or MSI) was finalized and populated with spring locations and associated information that had been assembled through previous projects. The Minnesota Spring Inventory currently holds approximately 6,900 features including a combination of field verified and likely, but non-verified locations. Field work during this funding period included most of the state with much of the activity focused on the greater Twin Cities area, east central (St. Croix River valley), and western Minnesota

(Minnesota River valley) for a total of 900 locations. Approximately 600 additional locations were added to the inventory through file searches, and an additional 200 likely locations were added through online citizen submittals with a DNR-created application.

Approximately 30 percent of the locations entered into the inventory during this funding period were seeps (groundwater flow rates less than a gallon per minute -- gpm). The remaining 70 percent of the locations were springs with flow rates as high as 100 gpm. Approximately 20 percent of the springs had flow rates of 10 gpm or greater. These higher flow locations were found in every portion of the state that was surveyed during this project.

These data can be accessed through the following link:https://www.dnr.state.mn.us/waters/groundwater_section/springs/msi.html. Data can be downloaded from the Minnesota Geospatial Commons: https://gisdata.mn.gov/dataset/env-mn-springs-inventory.

PROJECT RESULTS USE AND DISSEMINATION

In March 2018, the Minnesota Spring Inventory web page went live: https://www.dnr.state.mn.us/waters/groundwater_section/springs/msi.html. The webpage has an online, interactive map that allows users to quickly find information about springs throughout the state. The webpage also provides a link to a reporting app that can be used by citizens on a desktop or mobile devise to provide location and basic spring characteristic information. DNR staff evaluate these submittals for possible inclusion into the spring inventory. Background information about the project and springs are also available through the web page.

During this funding period the project was promoted (dissemination) through at least 28 formal documented outreach activities by 4 members of the spring inventory team including 17 presentations, 6 interviews and articles through media organizations, and 5 articles for science organizations. Numerous informal contacts have been made by team members and others.

Project Completed: 06/30/2019 **FINAL REPORT**

Enhancing Understanding of Minnesota River Aquatic Ecosystem

Subd. 03i $500,000 TF

Tony Sindt
MN DNR
20596 Hwy 7
Hutchinson, MN 55350
Phone: (320) 234-2550 x236
Email: anthony.sindt@state.mn.us
Web: http://www.dnr.state.mn.us/fishwildlife/index.html

Appropriation Language
$500,000 the second year is from the trust fund to the commissioner of natural resources to accelerate collection of baseline data to enhance understanding of the Minnesota River ecosystem, measure future impacts of changing climate and landscapes on the aquatic ecosystem, and guide future management efforts. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Land use practices, climate change, establishment of invasive species, conservation efforts, and other factors continually affect the Minnesota River ecosystem. This project accelerated collection of robust baseline datasets that provide a better understanding of plankton communities, physical habitat characteristics, backwater ecosystems, and sensitive fish species populations. These datasets provide the ability to better predict, measure, and understand future ecosystem changes. Specifically, we established a comprehensive understanding of lower trophic ecology in the Minnesota River by collecting 112 water chemistry, phytoplankton, and zooplankton samples across 7 sites and 16 months. We also quantified habitat features (e.g., longitudinal profiles, bathymetric maps) at 12 reaches along the Minnesota River and characterized fish communities inhabiting 12 unique backwater lakes. Lastly, we captured and tagged 85 Paddlefish and 391 Shovelnose Sturgeon from the Minnesota River providing an understanding of population dynamics (e.g., abundance, growth, recruitment, and mortality), habitat use, and movement patterns of these unique and understudied species. Our enhanced understanding of the Minnesota River ecosystem and information gained during this project will not only inform future monitoring efforts and guide management and restoration efforts, but also provide the critical ability to understand how the Minnesota River ecosystem responds to future changes. For instance, if invasive carps become established in the Minnesota River, we now have the ability to quantify consequent changes in plankton communities, displacement of backwater fish communities, and impacts on the Paddlefish population. Data collected during this project are publicly available for quantitative and qualitative analyses while accompanying in-depth reports for each project activity provide valuable context, interpretation, and comparisons with other aquatic ecosystems.

PROJECT RESULTS USE AND DISSEMINATION

Resulting from this project, we developed five comprehensive reports summarizing and analyzing the novel datasets we collected that provide important comparisons with other aquatic systems and discuss implications for future Minnesota River ecosystem monitoring and management (i.e., Activity 1 Final Report—Spatial and temporal trends of Minnesota River phytoplankton and zooplankton, Activity 2 Final Report—Evaluation of Minnesota River physical habitat features, Activity 3 Final Report—Minnesota River backwater fish communities, Activity 4A Final Report—Minnesota River Shovelnose Sturgeon: population dynamics and movement patterns, Activity 4B Final Report—Paddlefish inhabiting the Minnesota River). Condensed versions of the reports associated with activity one (e.g., plankton dynamics) and activity four (e.g., Shovelnose Sturgeon, Paddlefish) will be submitted for publication in open-access peer reviewed scientific journals (e.g., Journal of Fish and Wildlife Management; Journal of Freshwater Ecology). During the project, we provided project updates and preliminary results to scientific audiences at three annual meetings of the Minnesota Chapter of the American Fisheries Society and to members of the public at Hutchinson Area Avid Angler Meetings, Citizen Catfish Workgroup meetings, and a Minnesota River Congress meeting. Ultimately, we intend on providing data, project reports, and project summaries on the Minnesota River Fisheries page of the Minnesota Department of Natural Resources website (Minnesota River Fisheries Page). We are also seeking appropriate venues to present final project results with interested members of the public and other scientific and conservation entities as one of the most valuable outcomes of this project is the collection of novel datasets on important components of the Minnesota River ecosystem.

Project Completed: 06/30/2019 **FINAL REPORT**

Introducing and LCCMR Funded Minnesota River Project and Preliminary Telemetry Discoveries
Inventory of Minnesota River Backwater Fish Communities
Shovelnose Sturgeon and Paddlefish Populations and Movements in the Minnesota River
Minnesota River Paddlefish, Sturgeon, Backwaters, Plankton and More!
Project Summary: Activity 3 Inventory Minnesota River Backwater Fish Community

[Project Summary: Activity 4a Population Dynamics and Movement of Shovelnose Sturgeon]
[Project Summary: Activity 4b Evaluate Abundance and Movement of Minnesota River Paddlefish]
[Enhancing Understanding of the Minnesota River Ecosystem]

Improving Brook Trout Stream Habitat through Beaver Management

Subd. 03j $225,000 TF

Andrew Hafs
Bemidji State University
218A Sattgast Hall
Bemidji, MN 56601
Phone: (218) 755-2789
Email: andrew.hafs@bemidjistate.edu
Web: http://www.bemidjistate.edu/directory/facstaff/ahafs/

Appropriation Language
$225,000 the second year is from the trust fund to the Board of Trustees of the Minnesota State Colleges and Universities system for Bemidji State University to quantify how beaver activity influences habitat quality in streams for brook trout in northeastern Minnesota in order to improve current and future management practices. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

In Minnesota, beaver Castor canadensis are considered to have an overall negative effect on native brook trout Salvelinus fontinalis. Brook trout provide a valued and productive sport fishery to the North Shore streams of Lake Superior and since revival of the beaver population from past trapping and timber harvest, a reexamination of the complex ecological relationship where the two taxa interact is imperative.

Brook trout habitat data collection occurred on 79 stream sections and 21 beaver ponds spanning the North Shore during summers 2017 and 2018. Results indicated that there was no effect of beaver on brook trout habitat in sections downstream of beaver ponds. Brook trout habitat was dependent on microhabitat variables (depth, velocity, temperature) that are eminent in individual stream sites and growth was limited by velocity and prey availability. Results also indicated that 12 of the 21 beaver pond sites sampled contained suitable brook trout habitat, with dissolved oxygen identified as a threshold.

Since 1948, the beaver population has increased approximately 3-fold along the North Shore. Populations appear to have stabilized in the 1990s, and have remained at a similar size since that time. There is some variation in population trends among sub-watersheds, suggesting that local population and habitat characteristics are driving beaver population dynamics. Current population levels demonstrate that beavers have largely recovered from overharvest that occurred up through approximately 1900.

A focus on individual stream characteristics and beaver pond dissolved oxygen concentrations is recommended to achieve desired brook trout habitat and aid in the development of management strategies pertaining to these two taxa in North Shore, Lake Superior streams.

PROJECT RESULTS USE AND DISSEMINATION

Results from our work include a widely read review about beaver-trout interactions in the Western Great Lakes, a paper which has already generated significant conversations in the fisheries management world. Two MS theses were completed and will be made available through Bemidji State University and the University of Minnesota – Duluth libraries. Several other papers will soon be published in the peer-reviewed scientific literature that will highlight our research findings on 1) the effects of beaver activities on brook trout habitat, 2) population dynamics of beavers in northern Minnesota, and 3) historical changes in beaver ponds and dams in the Lake Superior Watershed of Minnesota.

Overall, we digitized and geo-recitified over 1,200 historical photos, which will be stored on servers at the University of Minnesota Borchart Map Library for others to use going forward. We will also be making all of our GIS layers derived from aerial photo interpretation publicly available through Minnesota's Geospatial Commons (https://gisdata.mn.gov/).

Finally results from the study were presented at numerous state, regional, national, and international meetings including but not limited to:

- Minnesota Forestry and Wildlife Research Review, 2017
- 8th International Beaver Symposium, 2018
- 78th Midwest Fish and Wildlife Conference, 2018
- Annual Meeting of the American Society of Mammalogists, 2018
- Minnesota American Fisheries Society Meeting, 2018
- 79th Midwest Fish and Wildlife Conference, 2019
- Annual Meeting of the Minnesota Chapter of The Wildlife Society, 2017, 2018, 2019

Project Completed: 06/30/2019 **FINAL REPORT**

Casting Light Article

A Review of Beaver-Salmonid Relationships and History of Management Actions in Western Great Lakes (USA) Region

UMN Master Thesis: Factors Influecing Beaver (*Castor canadensis*) Population Fluctuations, and Their Ecological Relationship with Salmonids

Bemidji Master Thesis: Effect on Beaver on Brook Trout Habitat in North Shore, Lake Superior Streams

---

Evaluate Temperature, Streamflow, and Hydrogeology Impact on Brook Trout Habitat

Subd. 03k $115,000 TF

Bob Tipping
Minnesota Department of Health
625 Robert Street North
St. Paul, MN 55164
Phone: (651) 201-4649
Email: bob.tipping@state.mn.us

Appropriation Language
$115,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Minnesota Geological Survey to evaluate links between southeastern Minnesota stream temperatures, trout habitat, and bedrock hydrogeology to improve trout stream management. This

appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The recent discovery of resurgent brook trout populations in southeastern Minnesota streams has led to increased interest in documenting and improving critical habitat for this native species. Distributed Temperature Sensing (DTS) technology using fiber optic cables, combined with detailed mapping of geologic conditions and hydraulic head were used to identify areas of preferential base flow at three southeastern Minnesota trout streams— East Indian Creek in Wabasha County, Trout Brook in Dakota County, and Valley Creek in Washington County. Results were compared to fish inventories conducted by the Minnesota Department of Natural Resources to evaluate influence of focused groundwater input on brook trout distribution and abundance. Continuous stream temperature measurements along one meter segments over distances up to 1900 meters were taken in winter when air and groundwater temperatures are most different. Transition from mixed populations of brown and brook trout to predominantly brook trout corresponded specific stream reaches showing preferential base flow inputs from groundwater.

At the regional scale, artesian conditions were compared to bedrock geology and brook trout abundance to locate areas where brook trout, including remnant brook trout, may be most successfully established. Brook trout are found in almost exclusively in streams where the Oneota Dolomite and underlying bedrock units are uppermost bedrock. Streams in these settings have springs characterized by relatively constant temperatures, and are supplied by groundwater in generally poor connection to the land surface compared to near-surface aquifers. As such, they have relatively low susceptibility to high turbidity and contaminant pulses resulting from extreme storm events. At both regional and local cases our work (see attached) demonstrates to natural resource managers the direct geologic control on hydraulic head conditions – particularly on vertical head gradients between bedrock layers and the role they play both in stream base flow and brook trout distribution and abundance.

PROJECT RESULTS USE AND DISSEMINATION

The attached report is currently being revised for release as an Open-File Report available publically via the University of Minnesota's Digital Conservancy (https://conservancy.umn.edu/), and for peer-reviewed journal submittal. As a project that includes a hybrid of disciplines, it is expected that results will be presented at meetings with both groundwater and natural resource management focus. To date, the results have been presented to a group of local residents and landowners from East Indian Creek in Wabasha County, organized by Jen Wahls, Landuse Outreach Coordinator for Wabasha County SWCD and by Nick Budde, student scholarship recipient at the Minnesota Groundwater Association Spring 2018 Conference (also attached).

Project Completed: 06/30/2019 **FINAL REPORT**

Evaluation of temperature, streamflow, and hydrogeology impact on brook trout habitat

---

Restoration of Elk to Northeastern Minnesota

Subd. 03l $300,000 TF

James Forester
U of MN
2003 Upper Buford Cir, 135 Skok Hall
St. Paul, MN 55108

Phone: (612) 626-6721
Email: jdforest@umn.edu
Web: http://foresterlab.cfans.umn.edu/

Appropriation Language
$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with the Fond du Lac Band and Rocky Mountain Elk Foundation to determine the habitat suitability and levels of public support for restoring elk to northeastern Minnesota. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Elk historically occupied most of Minnesota prior to the early 1900s, but now only 3 small groups occur in northwestern Minnesota. These groups are managed at low levels to reduce human-elk conflict. Forested areas of the state could avoid some conflict and see ecological and economic benefits from returning elk to the landscape. Evidence from other states indicates elk restoration can be successful, but success is dependent on forest management and public support for elk by local communities. This study examined the feasibility of restoring elk to 3 study areas in northeastern Minnesota. It provides information that will be useful for determining where elk restoration will be successful, should it occur, including information about social acceptance and habitat suitability. It resulted in 2 reports (McCann et al. 2019 and Walberg et al. 2019).

To assess landowner and local resident attitudes toward restoring elk to northeastern Minnesota, we surveyed 4,500 private landowners and 4,000 local residents. Eighty percent of landowners and 81% of local residents within the study areas strongly supported restoring elk to northeastern Minnesota. Landowner support for restoration was highest on the Cloquet Valley study area and lowest on the Fond du Lac study area. Local resident support was highest in southern St. Louis County, followed by Duluth, northern Pine County, and Carlton County.

To evaluate elk habitat suitability and to provide additional assessment of social support for restoring elk to northeastern Minnesota, we measured elk forage in the field and utilized GIS data to map habitat and social suitability. Our results show that habitat suitability and landowner support are not limiting factors for restoring elk to northeastern Minnesota. We sampled 186 field plots and found that mean summer forage at field plots exceeded amounts elk prefer and winter forage matched amounts where elk occur in Wisconsin. Estimates of how many elk are likely to be supported (5 to 8 elk/6 mi2) were similar to elk densities in Wisconsin and Michigan. Estimates of biological carrying capacity ranged from 287 on the Fond du Lac study area to 551 elk on the Cloquet Valley study area. Each of the 3 study areas: (1) had large amounts of habitat with suitability scores similar to where elk occur in Wisconsin; (2) a majority of land in public ownership; and (3) and relatively low human-elk conflict risk. Considering factors we assessed to be equally important did not result in statistically different study area rankings (on average, all 3 study areas were about the same) but some study areas ranked better than others when we weighted factors (considered some factor to be more important than others).

PROJECT RESULTS USE AND DISSEMINATION

Schrage delivered 16 presentations about this project to multiple groups, including: Rocky Mountain Elk Foundation banquets in Duluth and Prior Lake, the Minnesota Sharp-tailed Grouse Society in Hinckley, the Winton Historical Society, staff from the MNDNR's Northwest Region, the Minnesota Soil and Water Conservation District Forestry Association, the Breckinridge Chapter of the Izaak Walton League, Rocky Mountain Elk Foundation members in the Twin Cities, the Moose Lake Covenant Church Outdoor Expo, the annual meeting of the Minnesota Division of the Izaak Walton League, the Minnesota Forest Resources Partnership, St. Louis County Leaseholders, Northwoods Audubon, MNDNR Region 2 Assistant

Wildlife Managers, a joint meeting of Minnesota Forest Industries and MNDNR Forestry, and at a meeting of the St. Louis County Committee of the Whole. McCann and PhD student Eric Walberg delivered presentations about the project at the joint meeting of the State Chapters of The Wildlife Society and Society of American Foresters in Duluth, MN. Fulton and McCann delivered presentations about the project at the Western Association of Fish and Wildlife Agencies' Biennial Deer & Elk Workshop in Marfa, TX. This project was featured in the Duluth News Tribune, Pioneer Press, Brainerd Dispatch, the Minnesota Deer Hunters Association publication of "Whitetales", and Outdoor News. Educational displays about elk and this project were set up and staffed by tribal, Rocky Mountain Elk Foundation, University of Minnesota, and volunteer staff at the Carlton County and Minnesota State Fairs. Additionally, Schrage and other tribal personnel staffed booths that highlighted this project at the Minnesota State Fair and a second at the Cloquet Forestry Center's 50th anniversary celebration of their Conservation Education Day event, and Schrage and McCann ran an informational booth for the project at the Outdoor News Deer and Turkey Classic show. We held multiple project meetings that included MNDNR staff. We developed an internet presence, including a website (http://elk.umn.edu) and Facebook page (https://www.facebook.com/NE.MN.elk).

Project Completed: 06/30/2019 **FINAL REPORT**

A study of landowner and public attitudes toward potential elk restoration in Minnesota
Feasibility of restoring elk to northeastern Minnesota: habitat availibility and social acceptance

---

Game and Nongame Bird Pesticide Exposure

Research Project

Subd. 03m $349,000 TF

Julia Ponder
U of MN
1920 Fitch Ave
St. Paul, MN 55108
Phone: (612) 624-3431
Email: ponde003@umn.edu
Web: https://www.raptor.umn.edu/

Appropriation Language
$349,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to evaluate the potential risk to game and nongame birds from exposure to neonicotinoid-treated agricultural seeds. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Neonicotinoids are the most widely used pesticides worldwide and are commonly applied as a seed treatment to corn, soybean, and wheat seeds, which compromise the majority of Minnesota's row crops. Previous risk assessments have suggested that wild birds may be exposed to large doses of neonicotinoids through the ingestion of treated seeds. Using chickens as a model species, we evaluated the impacts of oral neonicotinoid exposure on the immune and neurological systems. We also assessed availability of treated seeds to wild birds on the agricultural landscape and analyzed grouse carcasses for residues of exposure. Accomplishments:

- We demonstrated neurological abnormalities in chickens exposed orally to imidacloprid, a commonly used neonicotinoid in seed-treatments
- We quantified seed spills on agricultural landscapes during spring planting season that may occur during loading or refilling seed hoppers
- We documented wildlife at neonicotinoid-treated seed spills with trail cameras and documented consumption of treated seeds.
- We documented neonicotinoid residues in the tissues of hunter-harvested grouse, indicating that those birds were exposed to the pesticides
- We identified 354 genes affected by imidacloprid exposure through RNA sequencing: 37 affected genes were detected in liver and 317 affected genes were detected in blood cells (which can be non-lethally collected, which may allow future development of detection assays)

The results of this project indicate that seed-eating birds in the wild may be exposed to seeds treated with neonicotinoids in the agricultural landscape through eating at seed spills. Ingestion of neonicotinoid-treated seeds by birds can produce neurological abnormalities that may impair survivability. Exposure can be evaluated through detection of pesticide residues in carcasses, as well as fecal pellets and blood cells. The results of this study may be used by the agricultural industry to reduce impacts to wild birds through education and process change (reduce spillage), as well as state and federal governmental agencies reviewing appropriate and safe usage of these pesticides.

PROJECT RESULTS USE AND DISSEMINATION

Results of this project have been communicated to a large audience of stakeholders, including directly with industry colleagues through meetings with agricultural stakeholders; with federal and state agencies through public commentary response as well as requested webinars, presentations and conversations; and with the scientific community through publications (1 paper published, 1 submitted and 4 pending), conference presentations (4) and scientific posters (2). Details of all communications are provided in the final report. The results of our work show that wild birds are at risk of exposure to agricultural seeds treated with neonicotinoids and that ingestion of field-realistic doses causes significant behavior changes in chickens that were severe at higher doses and may impair survival of free-living gallinaceous birds. The adoption of practices that would reduce seed spills on the agricultural landscape would reduce the exposure risk to wild birds.

Project Completed: 06/30/2019 **FINAL REPORT**

Report: Neonicotinoids on the Landscape

Multi-scale availability of neonicotiniod-treated seed for wildlife in an agricultural landscape during spring planting

---

Evaluating Insecticide Exposure Risk for Grassland Wildlife on Public Lands

Research Project

Subd. 03n $250,000 TF

Nicole Davros
MN DNR

35365 800th Ave
Madelia, MN 56062
Phone: (507) 578-8916
Email: nicole.davros@state.mn.us
Web: http://www.dnr.state.mn.us/wildlife/index.html

Appropriation Language
$250,000 the second year is from the trust fund to the commissioner of natural resources to evaluate exposure risks of grassland wildlife to soybean aphid insecticides, to guide grassland management in farmland regions of Minnesota for the protection of birds, beneficial insects, and other grassland wildlife. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Concerns about the impact of insecticides on birds, pollinators, and other wildlife are gaining increasing attention. Chlorpyrifos, lambda-cyhalothrin, and bifenthrin (hereafter, target chemicals) are three insecticides commonly used to control soybean aphids in Minnesota's farmland region. Lab studies have shown these chemicals to be highly toxic to non-target organisms including several bird and beneficial insect species, but few studies have investigated exposure of free-ranging wildlife to these chemicals. During 2017 and 2018, we collected samples from public grasslands across southwest, west central, and central Minnesota to determine direct and indirect exposure of wildlife to target chemicals, and indirect effects of the chemicals on insect prey important in the diets of grassland birds. We detected target chemicals at all distances examined (0-400 m from grassland edge) at both treatment and control sites, suggesting that some baseline amount of spray drift occurred in the environment regardless of landowner activities in the adjacent crop field. We also examined the importance of weather, vegetation, and other factors in explaining direct and indirect exposure. Notably, we found insecticide deposition directly onto passive sampling devices (used to measure direct exposure) was greater at the field edge than grassland interior, and deposition was also greater at mid-canopy than ground level. We also detected chemical residues on invertebrates (used to measure the potential for indirect exposure of insectivorous wildlife to these insecticides) but we did not find a strong relationship with distance from edge, possibly because we only evaluated indirect exposure ≤25 m from the field edge. We are currently evaluating the indirect effects of spray drift on invertebrate richness, diversity, and biomass. This fall, we will further interpret our findings to understand potential impacts (e.g., sublethal, lethal) of spray drift on various species of grassland wildlife. We will also begin more broadly sharing our findings with multiple constituent groups, including cooperating landowners, agricultural groups, and natural resource professionals. Ultimately, our research on the factors influencing soybean aphid insecticide deposition in grasslands in the agricultural matrix of Minnesota will help improve management of these set-aside habitats for wildlife.

PROJECT RESULTS USE AND DISSEMINATION

To date, we have presented our preliminary results at wildlife professional society conferences, DNR regional wildlife meetings, LCCMR/University of Minnesota (UM) pollinator and partner project meetings, graduate student symposia, and a webinar focused on prairie habitat conservation issues. We have also prepared annual progress reports for DNR and the USGS/Minnesota Cooperative Fish and Wildlife Research Unit. Finally, we have mentioned the study during several media interviews when appropriate. The final results of this research will form the main chapters of a Master's thesis for a graduate student at UM, and the thesis is expected to be completed during fall 2019 as part of her graduation requirements. These thesis chapters will be used to create peer-reviewed publications that will be shared with other scientists and natural resource professionals. We will continue to disseminate

our results with DNR wildlife managers and other staff so they can incorporate our findings into their habitat acquisition, restoration, and management activities. We will also share our findings with our private landowner cooperators and the larger agricultural community to bring awareness to the issue of and factors influencing soybean aphid insecticide drift onto grasslands and other set-aside habitats.

Project Completed: 06/30/2019 **FINAL REPORT**

MNDNR 2016 Annual Report: Insecticide Exposure Risk for Grassland Wildlife on Public Lands
MNDNR 2017 Annual Report: Insecticide Exposure Risk for Grassland Wildlife on Public Lands
Evaluating Insecticide Exposure Risk for Grassland Wildlife on Public Lands
MNDNR Fact sheet

Development of Innovative Cost-Saving Methodology for Forest Inventory

Research Project

Subd. 03o $800,000 TF

Dennis Kepler
MN DNR
483 Peterson Rd
Grand Rapids, MN 55744
Phone: (218) 322-2512
Email: dennis.kepler@state.mn.us
Web: https://www.dnr.state.mn.us/forestry/resource-assessment.html

Appropriation Language
$800,000 the second year is from the trust fund to the commissioner of natural resources to develop and pilot a new and more cost-effective methodology for an enhanced stand-based forest inventory, with the goal of extending the methodology statewide. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Comprehensive forest inventory systems are a universal desire, but the costs of maintaining such a system with boots on the ground, especially considering Minnesota's extensive and diverse forest land base, continue to be a challenge. This project served as an important pilot to explore the accuracies achieved and cost savings gained with changing the way forest inventory is conducted. Two field sampling methods were tested in this project in over 300 plots, measuring over 9,000 trees: fixed radius plots placed in a gridded array (pre-stratification) and random plots placed proportionately within strata (post-stratification). Model results show that a gridded allocation performs better and has greater flexibility to reduce/expand the number of plots without risking model performance. Several forest inventory models (combined forest types, broadleaf only, and conifer only) were evaluated using numerous spatial predictors and two sources of LiDAR data: new high density and old low density. Model results show higher accuracies for conifers compared to broadleaf for both sources of LiDAR, and the combined models showed high density LiDAR performs much better. Another area of exploration was mapping cover types, since this is a crucial characteristic of a forest stand. The suite of remotely sensed data used and machine learning techniques applied have enabled cover type mapping with relatively good accuracy. The forest inventory and cover type mapping results in this project are incredibly encouraging and the methods developed are ready for statewide application once high density LiDAR data are available. Overall, the project results show that using remotely sensed data can

cut inventory costs by about 55%, enables the analysis of this valuable information across all lands, makes data available much faster than traditional methods, and ultimately benefits the many agencies, organizations, and stakeholder groups who are hungry for an affordable change to how forest inventory is conducted.

PROJECT RESULTS USE AND DISSEMINATION

Analyses of the newly acquired high density LiDAR has resulted in several forest inventory metrics and cover type models created, utilizing more than 300 newly acquired field forest inventory plots with over 9,000 trees measured. All of the LiDAR and derived products will be provided free to the public and will be hosted as LiDAR point cloud files on an ftp server with other state LiDAR data holdings, as well as several web mapping services produced by the MNDNR and accessible via the Minnesota Geospatial Data Commons (https://gisdata.mn.gov/). The project team from DNR Resource Assessment has already and will continue to deliver the results of this project in a number of other ways, including presentations at regional and national conferences in the fields of forestry, geographic information systems, and remote sensing, meetings and conference calls to share information directly with stakeholder groups, as well as the eventual submission of peer-reviewed manuscripts to scientific journals. In addition, DNR Resource Assessment has created a webpage that will be a central repository for all of the methods, reports, and links to access data.

Project Completed: 06/30/2019 **FINAL REPORT**

Evaluation of Tree Retention Guidelines Pertaining to Wildlife - RESEARCH

Subd. 03p $232,000 TF

Gerald Niemi & Alexis Grinde
U of MN - NRRI
5013 Miller Trunk Hwy
Duluth, MN 55811
Phone: (218) 788-2670
Email: gniemi@nrri.umn.edu
Web: http://www.nrri.umn.edu

Appropriation Language
$232,000 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 assess the effectiveness of the Minnesota Forest Resources Council tree retention guidelines in sustaining Minnesota's wildlife populations, by quantifying and evaluating the impacts on birds, small mammals, and amphibian diversity. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Forest management is increasingly focused on maintaining ecological functions, including maintenance of biodiversity and wildlife habitat. In 1998, the Minnesota Forest Resources Council (MFRC) established Minnesota’s Forest Management Guidelines, which were intended to reduce the potential for negative environmental impacts resulting from forest harvesting. The current guidelines recommend that 6-12 trees per acre or 5 percent of the harvest area in 0.25 acre clumps or greater be retained (left uncut) for wildlife and biodiversity benefits. The spatial arrangement of retained trees influence habitat suitability for wildlife species, but there is a lack of information on what configuration of tree retention will

maximize wildlife benefits. To examine and quantify the benefits of tree retention after logging on Minnesota's wildlife, we measured breeding bird and small mammal diversity by conducting systematic surveys at four experimental study areas and 69 sites that had been harvested between three and 15 years previously. We then quantified the habitat characteristics including tree retention density and configuration at harvest sites. Our results showed there is a positive relationship between tree retention and wildlife diversity. The clumped configuration was most beneficial for small mammal communities. Stands with clumped tree retention also maintained bird diversity over time and significantly increased the relative abundance of several breeding bird species. Overall, the results indicated that the current MFRC guidelines are beneficial for wildlife and increase the diversity and total abundance of bird and small mammal species that use forest stands post-harvest. We recommend that the MFRC continue to promote clumped tree retention, or the use of a combination of clumped and scattered retention, to mitigate harvest-related impacts to Minnesota's wildlife. The results of this project add to the scientific basis for MFRC's forest management guidelines and provide support for sustainable management of Minnesota's forest resources.

PROJECT RESULTS USE AND DISSEMINATION

The results of this project have been presented at a variety of workshops and conferences:

- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 11, 2018.
- The Minnesota Chapter of The Wildlife Society Meeting, St. Cloud Minnesota, February 12-14, 2018.
- Charting the Future for Northern Forest Birds: Takin it to the Tweets workshop in Ashland, WI, April 16-17, 2018.
- Forestry for Lake States Birds, Long Lake Conservation Center, June 22-23, 2018.
- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 10, 2019 and The Minnesota Chapter of The Wildlife Society Meeting, Duluth Minnesota, February 19-21, 2019.
- The results of this report were presented to the MFRC on March 14th, 2019 and the PDF version of the presentation is included with the final report submission.
- The results of this project were featured in NRRI's newsletter and can be found here: https://www.nrri.umn.edu/natural-resources-research-institute/news/tree-retention
- We are in the process of completing two peer-reviewed manuscripts for this project and plan to have them submitted by the end of the year; the manuscripts will be available on NRRI's website after they are published.
- The final report will be posted on the NRRI website.
- Results from this work will also be used by the MFRC during the next revision of the guidelines, contributing to the scientific basis for forest management guidelines to sustainably manage Minnesota's forest resources.

Project Completed: 06/30/2019 **FINAL REPORT**

Determine Impacts on Wildlife From Emerald Ash Borer Infection of Black Ash Forests

Research Project

Subd. 03q $334,000 TF

Gerald Niemi
U of MN - NRRI
5013 Miller Trunk Hwy
Duluth, MN 55811
Phone: (218) 788-2670
Email: gniemi@nrri.umn.edu
Web: http://www.nrri.umn.edu

Appropriation Language
$334,000 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 assess impacts of emerald ash borer and adaptive management on wildlife diversity in black ash forests and to develop recommendations to mitigate wildlife impacts. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Black ash wetlands cover over one million acres of northern Minnesota forests and provide critical habitat for wildlife. The future of Minnesota's black ash swamps is critically threatened by EAB, which has been eliminating native populations of ash throughout the Great Lakes Region. Although EAB impacts to wildlife are certain, the magnitude and relative degree of impact to individual species and species diversity is unclear. To quantify the impacts of EAB on wildlife we measured seasonal bird, mammal, and herptile diversity in black ash stands across Minnesota. We established 29 long-term monitoring plots and developed protocols for measuring the current status of wildlife communities and also used eight experimental research sites that simulated EAB mortality and adaptive management strategies for EAB (clearcutting and group selection harvests) to assess the impacts of EAB on wildlife communities. Our results show that black ash stands are structurally and compositionally more diverse than paired upland and emergent habitats, providing a variety of microhabitats that support a large and unique assemblage of birds and amphibians. The loss of black ash due to EAB will result in turnover of bird, amphibian, and mammal communities from forest dependent species to open-canopy and wetland associated species. Increased ponding and hydroperiods may be beneficial for some amphibian species, but the loss of the forest canopy will result in an overall decrease in bird diversity, reduce forest connectivity, and exacerbate impacts of habitat loss for many mammal species. Our results show that the long-term, large-scale impacts of EAB on forest-associated wildlife will be significant. Management strategies that focus on establishing alternative trees species to maintain long-term forest cover and structural complexity will help maintain and conserve wildlife diversity.

PROJECT RESULTS USE AND DISSEMINATION

The results of this project have been presented at a variety of workshops, conferences and included in the following publications:

- Joint Meeting of Ichthyologists and Herpetologists "Potential effects of emerald ash borer invasion on wetland community composition" in Austin TX, July 12-16, 2017.
- Science and Management of Ash Forests after Emerald Ash Borer: A workshop on the future of post-EAB ash forests "Potential effects of emerald ash borer invasion on wetland community composition" in Duluth, MN on July 25-27, 2017.
- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 11, 2018.
- The Minnesota Chapter of The Wildlife Society Meeting, St. Cloud Minnesota, February 12-14, 2018.

- Charting the Future for Northern Forest Birds: Takin it to the Tweets workshop in Ashland, WI, April 16-17, 2018.
- Alexis Grinde presented a webinar “Determining Impacts on Wildlife From Emerald Ash Borer Infestations of Black Ash Forests” via EAB University on March 15, 2018. The webinar recording is available at http://www.emeraldashborer.info/eabu.php
- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 10, 2019
- The Minnesota Chapter of The Wildlife Society Meeting, Duluth Minnesota, February 19-21, 2019.
- Rob Slesak and Alexis Grinde presented “EAB and black as wetlands: Holistic assessment of ecosystem impacts and potential for mitigation” at the Forest Resources monthly seminar on February 25, 2019. Recording is available on the Sustainable Forests Education Cooperative: https://youtu.be/9R5QKKNNMYU
- Alexis Grinde presented a poster “Emerald Ash Borer and Wildlife: A Look into the Future” at the 2019 Heart of the Continent Symposium in Duluth, MN on April 8, 2019.
- Melissa Youngquist gave a seminar "Potential effects of emerald ash borer invasion on wetland communities" at Arkansas State University on April 24, 2019.
- Melissa Youngquist presented "Protecting Our Threatened Wetlands: How Invasive Species Can Affect Wetland Communities." At the Shedd Aquarium on May 15, 2019.
- Rob Slesak discussed the implications of the work at MN Senate and House hearings during the 2019 legislative session.
- Rob Slesak gave an invited presentation “Impacts of Emerald ash borer on black ash in the lake states” at the Eastern Regional Meeting of the National Council on Air and Stream Improvement, Atlanta GA, June 4, 2019.
- Rob Slesak gave an invited presentation “Simulated effects of EAB on hydrology of black ash wetlands” at the Water and Watersheds annual conference of the MN Pollution Control Agency, Brainerd MN, February 6, 2019.
- Kolka, R.K., D’Amato, A.W., Wagenbrenner, J.W., Slesak, R.A., Pypker, T.G., Youngquist, M.B., Grinde, A.R. and Palik, B.J., 2018. Review of Ecosystem Level Impacts of Emerald Ash Borer on Black Ash Wetlands: What Does the Future Hold?. Forests, 9(4), p.179. https://www.fs.fed.us/nrs/pubs/jrnl/2018/nrs_2018_kolka_001.pdf
- The results of this project were incorporated into the updated version of the document “Managing Ash Woodlands: Recommendations for Minnesota Woodland Owners” this document is available on the UMN Digital Conservancy on-line and in a variety of print options. The persistent link to this item is: http://hdl.handle.net/11299/205052
- We are in the process of completing two peer-reviewed manuscripts for this project and plan to have them submitted by the end of the year; the manuscripts will be available on NRRI’s website after they are published.

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 04 Water Resources

Tracking and Preventing Harmful Algal Blooms

Research Project

Subd. 04a $593,000 TF

Daniel Engstrom
Science Museum of Minnesota
St. Croix Watershed Research Station, 16910 152nd St N
Marine on St Croix, MN 55047
Phone: (651) 433-5953
Email: dre@smm.org
Web: https://www.smm.org/scwrs

Appropriation Language
$500,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix Watershed Research Station to identify species composition and timing of harmful algal blooms, understand the causes of bloom development in individual lakes, and determine how nutrients and climate interact to increase harmful algae outbreaks. This work must be done in cooperation with the University of Minnesota and the Minnesota Pollution Control Agency. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Lakes are one of Minnesota's most precious resources and harmful algal blooms (HABs) threaten them both from an ecological and economic standpoint. This provides a survey of the current prevalence and toxicity of harmful algal blooms (HABs) in a subset of Minnesota lakes, determines if these blooms are increasing in frequency, and develops and refines modeling techniques that could be used to predict HABs in lakes across Minnesota. To this end, we intensively monitored five lakes in southwest and central Minnesota over 2 years for all major water chemistry parameters, algal biomass, and four cyanotoxins. In these lakes, and five additional lakes in northern Minnesota, we collected and dated sediment cores where fossil cyanobacterial pigments could be measured to track the occurrence of Cyanobacteria over the last 150 years. Finally, we chose one of the intensively monitored lake as a pilot study where we developed a watershed model (SWAT) and an in-lake hydrodynamic model (CE-QUAL-W2) to predict annual cyanobacterial bloom patterns. As a result of this project, we determined that in lakes which are already eutrophic, internal loading dynamics will play a key role in determining the size and toxicity of the bloom. Importantly, we found that even in shallow lakes (less than 16 ft maximum depth), temperature and oxygen dynamics are critical in terms of bloom timing and toxicity. Cyanobacteria pigment data from our sediment cores showed increasing HABs in some lakes over the 20th Century, but also demonstrate that conditions may have been even worse in the early to mid- 20th Century before the passage of the Clean Water Act. Our modeling results provide a framework for resource managers to predict seasonal bloom formation and persistence in lakes across the state using publicly available and widely used modeling techniques.

PROJECT RESULTS USE AND DISSEMINATION

Throughout this project we have provided numerous public updates on progress via the Science Museum of Minnesota's website and the St. Croix Watershed Research Station's blog, "Field Notes" including:

- "Featured Research Project" on SCWRS website: https://www.smm.org/scwrs/research/hab

- "Watching When, Where and Why Harmful Algae Happen in Minnesota Lakes" describing the beginning of the project: https://www.smm.org/scwrs/fieldnotes/watching-when-where-and-why-harmful-algae-happen-minnesota-lakes
- A primer on the "5 super powers of Cyanobacteria": https://www.smm.org/scwrs/fieldnotes/five-super-powers-cyanobacteria

We provided our expertise in major statewide news coverage of HABs over the course of this project, including:

- "Dogs as sentinels: Blue-green algae brings toxic mystery to Minn. Waters": https://www.mprnews.org/story/2016/05/24/water-toxic-algae-dogs-climate-change
- Two evening news spots on FOX21 Duluth in June of 2017 where reporters accompanied us in the field
- "Researchers search for clues to toxic algae blooms": https://www.mprnews.org/story/2017/08/17/researchers-search-for-clues-to-toxic-algae-blooms
- Participated in public call-in show on MPR for Minnesotans with questions about their lakes: https://www.mprnews.org/story/2018/04/03/water-month-state-of-minnesotas-lakes
- Participated in MPRs Climate Cast on the topic of HABs: https://www.mprnews.org/episode/2019/07/19/conditions-ripe-for-a-record-number-of-algae-blooms?fbclid=IwAR19XRU6hUPGjIt9-9d0Pj8H5pRfPLEYWSr-SpdE-g7yTlAANwQmZU7IaqQ

We co-organized two public workshops on HABs in cooperation with the University of Minnesota St. Anthony Falls Laboratory that were held in March of 2017 and 2018 which were each attended by ~70 people, including state agency personnel, local water district managers, academic researchers, private environmental consultants, and interested members of the public.

Major research results from this project were also presented at two separate meetings of the Association for the Sciences of Limnology and Oceanography in June of 2018 and February of 2019 using in-kind funding provided by the Science Museum of Minnesota. This is the largest meeting dedicated to aquatic science in the world and is held once a year. A PDF of the scientific poster presented in 2018 and the powerpoint presented in 2019 are included as a supplemental attachment to this report.

Additional Attachments include fact sheets created by SCWRS for HABs on Pearl Lake and the Madison Lake SWAT model and a report on the CE-QUAL-W2 model produced by USGS.

Project Completed: 06/30/2019 **FINAL REPORT**

USGS Report: Updates to the Madison Lake (Minnesota) CE-QUAL-W2 Water-Quality Model..
SCWRS Fact Sheet

Assessing the Increasing Harmful Algal Blooms in Minnesota Lakes

Research Project

Subd. 04b M.L. 2016 - $270,000 TF and M.L. 2015 - $71,000 TF

Miki Hondzo
U of MN - St. Anthony Falls Laboratory

2 Third Ave SE
Minneapolis, MN 55414
Phone: (612) 625-0053
Email: mhondzo@umn.edu
Web: http://www.safl.umn.edu

Appropriation Language
M.L. 2016, Chp. 186, Sec. 2, Subd. 04b
$270,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Saint Anthony Falls Laboratory to investigate lake processes and meteorological conditions triggering algal blooms and toxin production, develop models for tracking blooms, and provide outreach on the prediction, detection, and impacts of mitigation of algal bloom events. This work must be done in cooperation with the St. Croix Watershed Research Station of the Science Museum of Minnesota and the Minnesota Pollution Control Agency. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.
M.L. 2015, Chp. 76, Sec. 2, Subd. 10 - Emerging Issues Account (recieved $71,000)
$1,000,000 the first year is from the trust fund to emerging issues account authorized in Minnesota Statutes, section 116P.08, subdivision 4, paragraph (d).

OVERALL PROJECT OUTCOME AND RESULTS

Harmful algae, including cyanobacteria, have been populating a growing number of freshwater ecosystems including lakes, rivers, and wetlands in Minnesota. Excessive accumulation of harmful algal biomass and associated toxin generation is referred to the public as a harmful algal bloom (HAB). The algal toxins, called microcystins, are harmful to wildlife and humans. The overall objective of this study was to determine how lake physical processes and meteorological conditions control HABs in three Minnesota lakes. We designed and implemented a unique research station to document HABs and toxin generation. This research station provides full-depth water quality (hourly) and meteorological conditions monitoring (5 min) at the sampling site and the display of data over the Internet. The high cyanobacteria biovolume (BV) in the approximate 4 m of the lake surface water depth was observed in mid-July and persisted until late September. Two types of BV distributions were observed. The first distribution depicted BV uniformly distributed over the surface water depth, and the second BV distribution displayed local underwater BV maxima. A quantitative relationship was developed to determine the anticipation of observing a uniform or underwater peak distribution as a function of the lake physical and meteorological conditions. Toxin microcystins (MC) was observed to accumulate in the lake surface layer and had a vertical distribution similar to BV. The temporal variabilities of BV and MC were different. The maximum toxin concentration occurred on average, seven days before or after the maximum HAB concentration was established. The time-lag between the maxima of BV and MC is notable because the maximum toxin concentration could occur before the visual signs of enhanced cyanobacterial accrual are less recognizable to the public and monitoring. Our findings could have important implications for predicting toxin and cyanobacterial biomass distribution and guiding monitoring strategies for quantifying toxin concentrations in Minnesota lakes.

PROJECT RESULTS USE AND DISSEMINATION

Public education and outreach were an integral part of our project. We had a total of 19 separate outreach and educational activities. We held six (6) different public outreach activities conducting over 365 different individual conversations and conducted five (5) in-person workshops with over 460 participants. The project produced three (3) peer-reviewed publications (attached to this report). A new HAB focused webpage was also developed, which remains active. We also purchase, retrofitted, and set-

up a mobile educational trailer to provide hands-on HAB educational activities, including demonstrating the use of drones and spectral camera in detecting and monitoring HABs.

Project Completed: 06/30/2019 **FINAL REPORT**

Restoring Native Mussels in Streams and Lakes

Subd. 04c $600,000 TF

Mike Davis
MN DNR
2109 Lakeshore Dr N
Lake City, MN 55041
Phone: (507) 251-4116
Email: mike.davis@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$600,000 the second year is from the trust fund to the commissioner of natural resources in cooperation with the Minnesota Zoological Garden for a statewide mussel program to rear, restore, and re-establish native mussel species in streams and rivers. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota's native mussels are critically important to aquatic ecosystems, but have been lost or diminished in many water bodies. Harvest for pearls and buttons, pollution, dams, and destabilized waterways have caused mussel populations to decline dramatically, 80% of Minnesota's species are effected. Improvements from Clean Water Act implementation and stream restoration work are creating opportunities to reverse this trend. Mussel dependence on fish hosting their larval stage, and dams blocking fish movement can prevent populations from recovering limiting ecosystem recovery. Laboratory propagation began in 2016 as a means to reestablish mussel assemblages and the ecosystem services mussels provide. Three watersheds were selected for reintroduction efforts based on historical mussel records, habitat type and fish communities. We constructed several propagation systems specifically designed for juvenile recovery and culture over this period. In total, the Center for Aquatic Mollusk Programs (CAMP) has produced 1,332,592 juveniles of eleven species. In addition, almost 1,000 inoculated fishes were placed in benthic plastic totes or metal cages. The range of survival in the laboratory after 90 days ranges from 0 – 84%; Mucket and Black Sandshell have been our most successful species. Almost 75,000 juvenile mussels were raised to 2mm in length and moved into secondary culture systems for continued growth for release within two years. By restoring mussels, we hope to recover mussel species and improve water clarity. Recovering mussels will improve habitat for fish communities. Minnesotan's value clean water and fish; this project intends to enhance both.

PROJECT RESULTS USE AND DISSEMINATION

The results of this project has been featured in the Minnesota Conversation Volunteer in the September – October 2019 edition. Our Mussels of Minnesota poster was updated with all new photographs and text, and published in June 2019. CAMP's annual mussel newsletter generated attention, and our subscriber numbers have increased to over 2,300.

Project Completed: 06/30/2019 **FINAL REPORT**

Assessing Techniques for Eliminating Contaminants to Protect Native Fish and Mussels

Research Project

Subd. 04d $287,000

Kristine Wammer
University of St Thomas
2115 Summit Ave, JRC 153
St. Paul, MN 55105
Phone: (651) 962-6012
Email: khwammer@stthomas.edu
Web: http://www.stthomas.edu

Appropriation Language
$287,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the University of St. Thomas to evaluate the use of ultraviolet treatment of wastewater to remove certain commonly detected wastewater contaminants, in order to reduce the contaminants' toxicity to native fish and mussels. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

In 2009 the MPCA was directed by the legislature to monitor surface waters for endocrine disrupting compounds near wastewater treatment plants. In the resultant study, two of the most commonly detected compounds (tonalide and galaxolide) were polycyclic musks that are used as synthetic fragrances in a wide range of products. It has been demonstrated in mussels that musks can impair transporters involved in the first line of defense against toxicants. This is of great concern as 25 of Minnesota's 48 native mussel species are listed as endangered, threatened, or of special concern. Tonalide and galaxolide are also known to induce other types of toxicity (e.g. liver damage, DNA/genetic damage) and are suspected endocrine disruptors, meaning they can disrupt hormones and impair growth and reproduction, and are thus a potential threat to mussel and fish populations.

The goal of this project was to assess whether UV treatment of wastewater can effectively remove toxicity attributable to these compounds. When tonalide was exposed to sufficient UV light, it was eliminated and several photoproducts were formed. Biological assays were performed using tonalide and confirmed endocrine activity and inhibition of transporters as predicted, but only at high concentrations that would not be typically expected in Minnesota waters. Furthermore, biological effects were largely reduced or eliminated upon exposure to UV, suggesting photoproducts do not retain significant biological activity of the parent compound. Analysis of wastewater effluents reveals the presence of some parent tonalide and some photoproducts, supporting the prediction that higher UV doses than currently used may be required to completely remove tonalide. A major finding of this project is that galaxolide is much less stable in water than previously reported; it is unlikely to persist and be of concern in environmental waters. Therefore, overall this study suggests polycyclic musks are unlikely to be an imminent threat at the levels detected in Minnesota waters.

PROJECT RESULTS USE AND DISSEMINATION

Results from this project have, to date, been disseminated primarily via presentations given by undergraduate students from Gustavus and the University of St. Thomas. Locally, this included the 2019 "Scholars at the Capitol" event. Nationally, students have presented at American Chemical Society and

Society for Environmental Toxicology and Chemistry meetings; internationally, a student presented at the International Symposium on Liquid Phase Separations. Because the bulk of the substantive results have been finalized in the past few months, preparation of manuscripts for submission to peer-reviewed journals are forthcoming.

Project Completed: 06/30/2019 **FINAL REPORT**

Assessing Neonicotinoid Insecticide Effects on Aquatic and Soil Communities

Research Project

Subd. 04e $400,000 TF

William Arnold
U of MN
500 Pillsbury Dr SE
Minneapolis, MN 55455
Phone: (612) 526-8582
Email: arnol032@umn.edu
Web: www.cege.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 identify neonicotinoid insecticide breakdown components produced in water and plant leaves and assess their toxicity to soil and aquatic species and related biotic communities. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Neonicotinoid insecticides are widely used and detected at varying concentrations across diverse environments, including soil, surface water, and groundwater. A key component of how persistent neonicotinoids are in the environment is their degradation rate, and the residual toxicity of the products needs evaluation. Hydrolysis is the reaction process that occurs in water, which may be affected by the pH of the water or the presence of natural trace metals and minerals. Reaction driven by sunlight (photolysis) has also been reported as an important transformation pathway for neonicotinoids. The objectives of this study were to quantify hydrolysis and photolysis rates for neonicotinoid insecticides in water and on various surfaces; understand the effects of pH and natural trace metals on hydrolysis of neonicotinoids; characterize transformation products; and assess the toxicity of hydrolysis and photolysis products to soil and aquatic species. Hydrolysis and photolysis in aqueous solutions and on surfaces were examined for various neonicotinoids, including imidacloprid, thiamethoxam, clothianidin, acetamiprid, and nitenpyram. The results showed that neonicotinoids undergo base-catalyzed hydrolysis, and the hydrolysis rates were not impacted in the presence of divalent metal cations and minerals. Direct photolysis was observed for nitenpyram, imidacloprid, thiamethoxam, and clothianidin, but not for acetamiprid. When put onto various model surfaces to simulate application to a plant leaf, the photolysis rates and mechanisms were not only dependent on the surface, but also on whether a commercial formulation or solution of pure compound (analytical standard dissolved in ultrapure water) of the pesticide was used. Photolysis of commercial products was faster than pure compounds on the tested surfaces. Product analysis indicated that the urea derivative was the most commonly detected product for neonicotinoids reacting via hydrolysis and photolysis in water, while reduction and dissociation of the nitro group led to the major photoreaction products on surfaces. Toxicity tests on

mosquito (Culex pipiens) larvae were conducted with nitenpyram, imidacloprid, acetamiprid, thiamethoxam, clothianidin, and their reaction products generated via hydrolysis, photolysis in water, and photolysis on surfaces. No residual toxicity associated with reaction products was observed.

PROJECT RESULTS USE AND DISSEMINATION

Results from the work have been presented as oral and poster presentations at conferences (2017 Minnesota Water Resources Conference, 2017 MN Conference on the Environment, 2017 Society of Environmental Toxicology and Chemistry (SETAC) national meeting, 2019 American Chemical Society National meeting, 2019 Association of Environmental Engineering and Science Professors Conference). The paper "Neonicotinoid insecticide hydrolysis and photolysis: Rates and residual toxicity" was published in the journal Environmental Toxicology and Chemistry. It is open access and freely available at: https://doi.org/10.1002/etc.4256. The associated data set is archived at http://hdl.handle.net/11299/199764. Mr. Stephen Todey's MS Thesis is available via ProQuest (https://search-proquest-com.ezp3.lib.umn.edu/docview/2268373263) and will shortly be archived in the University of Minnesota Digital Conservancy. We are preparing a manuscript that describes the photolysis and toxicity results for experiments performed on surfaces. The findings from this project will aid the development of guidelines for the management and safe use of neonicotinoids to protect the health of Minnesota's waters.

Project Completed: 06/30/2019 **FINAL REPORT**

Environmental Chemistry Paper - Neonicotinoid Insecticide Hydrolysis and Photolysis: Rates and Residual Toxicity
Photolysis of Neonicotinoid Insecticide in systems simulating leaf surfaces: Rates and Toxicity Assessments Presentation

---

Bacterial Assessment of Groundwater Supplies Used for Drinking Water

Research Project

Subd. 04f $299,000 TF

Raymond Hozalski
U of MN
500 Pillsbury Dr SE
Minneapolis, MN 55455
Phone: (612) 626-9650
Email: hozal001@umn.edu

Appropriation Language
$299,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to characterize and analyze bacterial communities in Minnesota groundwater used as drinking water supplies and link the microbiological data to other water quality indicators for drinking water supply safety. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Recent reports out of the neighboring states of Wisconsin and Iowa have suggested that drinking water supplies obtained from groundwater wells can be contaminated with disease-causing microorganisms (i.e., pathogens), including viruses and bacteria. The main goal of this study was to assess the

microbiological quality of groundwater supplies in Minnesota with an emphasis on disease-causing bacteria. In this study, microorganisms were collected from large volumes of water (100 to 400 gallons) using a filtration system from 16 public groundwater systems throughout the State of Minnesota. The groundwater wells varied in depth from 37 to 1,204 feet and in the relative age of the groundwater. The groundwater systems were sampled at the wellhead or source, after treatment if any (i.e., two systems did not disinfect before distribution), and from one location in the distribution system. With one exception, the groundwater supplies were free of enteric pathogens (i.e., pathogens with a conventional fecal-oral exposure route that cause gastrointestinal infections). Escherichia coli (i.e., E. coli) was only detected in water from a non-potable well with a documented history of contamination. Legionella, bacteria that are considered opportunistic pathogens, were detected in four of the 16 public groundwater supplies. Legionella can cause potentially fatal lung infections in people with weakened immune systems such as the elderly and chemotherapy patients. Legionella levels decreased substantially in a system employing chlorine disinfection. The results from this study suggest that groundwaters supplying public water systems in Minnesota are largely free of enteric pathogens but may contain opportunistic pathogens. This research also suggests that lower bacteria concentrations in groundwater is generally associated with deeper wells (i.e., > 150 ft) extracting older groundwater. Disinfection should be considered for systems with shallow wells (i.e., < 150 ft) due to the potential for high bacteria concentrations and to control opportunistic pathogens when present.

PROJECT RESULTS USE AND DISSEMINATION

Dissemination activities included two poster presentations and one oral presentation by graduate student John Galt. John presented a poster entitled “Are Waterborne Pathogens in Minnesota’s Groundwater?” at the annual Minnesota Section AWWA Conference in Duluth, MN on September 14, 2017. John also presented a poster entitled “Are Waterborne Pathogens in Minnesota’s Groundwater?” at the AWWA Water Quality Technology Conference in Portland, OR on November 12, 2017. An oral presentation on the work was delivered by John at the Minnesota Section of the American Water Works Association meeting in Duluth, MN in Fall 2018. The MN Section AWWA meeting is an important audience for the work as it includes representatives from water utilities around the state, consulting engineers that work in the state and region, and representatives from state agencies (e.g., MDH). Tim LaPara also participated in outreach activities. Tim gave an oral presentation on the project findings at the Minnesota Section of the American Water Works Association meeting in Duluth, MN in Fall 2019. Tim also spoke to the City of Riverton's City Council and to the water quality manager at the City of Eagan about the results. Finally, Tim also participated in an open house concerning the water system in the City of Hastings.

Project Completed: 06/30/2019 **FINAL REPORT**

Understanding Bedrock Fracture Flow to Improve Groundwater Quality

Subd. 04g $183,000 TF

Anthony Runkel
U of MN - MN Geological Survey
2609 Territorial Rd
St. Paul, MN 55114
Phone: (612) 626-1822
Email: runke001@umn.edu
Web: http://www.mngs.umn.edu/

Appropriation Language
$183,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Minnesota Geological Survey to use new techniques of borehole testing and rock fracture mapping in the Twin Cities metropolitan area to achieve a better understanding of groundwater flow through fractured bedrock, in order to improve groundwater management. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The goal of this project was to gain an improved understanding of groundwater flow through fractured limestone bedrock by using recently developed techniques. We focused on the Platteville Formation in the Twin Cities Metropolitan area, where the formation is one of the most heavily contaminated bedrock layers in the state. There were two primary activities. One was collection of a variety of geologic and hydrologic information from monitor wells. This was accomplished at two sites near the Mississippi River in Minneapolis; on the campus of the University of Minnesota, and near Minnehaha Falls. We used recently developed techniques that included borehole geophysical testing and instrumentation with multiple pressure and temperature sensors. Two monitor wells at each site were instrumented with sensors. A second activity was detailed mapping of fractures at an exposure of the Platteville Formation at the UMN campus site. Determining how water travels through the Platteville is achieved by combining the results of these two activities.

The project results greatly improved our understanding of how groundwater moves through the Platteville Formation. A key outcome was identification of predictable low permeability layers within the Platteville Formation that can hinder vertical transport of contaminants. The presence of these layers means that conventional techniques for monitoring and remediating contamination plumes would not be as effective as presumed. The results of our project can also be used in groundwater models to improve their accuracy to guide water management engineering. The relevance of our results to how groundwater contamination is characterized and remediated, and to water quantity issues, applies not only to the Platteville Formation, but to all fractured rock aquifers and aquitards in Minnesota. The rigorous techniques such as the inexpensive and efficient methods used in this project can therefore be used to improve water quality across much of Minnesota. A summary report provides greater detail on all the results of this project and their relevance.

PROJECT RESULTS USE AND DISSEMINATION

We have presented our results as the project progressed to water resources groups at the Minnesota Department of Health, Minnesota Pollution Control Agency, the regional division of the American Institute for Professional Geologists, and to local colleges training students who will ultimately become the next generation of groundwater managers in Minnesota. Our results will continue to be disseminated in this fashion, and in published reports. A summary report with greater detail on all our results is already available.

Project Completed: 06/30/2019 **FINAL REPORT**

Protection of State's Confined Drinking Water Aquifers - PhaseII

Research Project

Subd. 04h $433,000 TF

Jared Trost
US Geological Survey

2280 Woodale Dr
Mounds View, MN 55112
Phone: (763) 783-3205
Email: jtrost@usgs.gov
Web: http://mn.water.usgs.gov/index.html

Appropriation Language
$433,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the United States Geological Survey to continue to test methods of defining properties of confined drinking water aquifers, in order to improve water management. This appropriation is not subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Confined (or buried) aquifers of glacial origin overlain by till confining units provide drinking water to hundreds of thousands of Minnesota residents. The sustainability of these groundwater resources is not well understood because hydraulic properties of till that control vertical groundwater fluxes (leakage) to underlying aquifers are largely unknown. The U.S. Geological Survey, Iowa State University, Minnesota Geological Survey and Minnesota Department of Health investigated hydraulic properties and groundwater flow through till confining units using field studies and heuristic MODFLOW simulations. Till confining units in each of four major geologic deposits were characterized (location in parentheses): the Des Moines lobe (Litchfield), Superior lobe (Cromwell), Wadena lobe (Hydrogeology field camp [HFC] near Akeley), and Pre-Illinoian deposits (Olivia). Hydraulic and geochemical field data were collected from sediment cores and a series of five piezometer nests. Each nest consisted of five to eight piezometers screened at short vertical intervals in hydrostratigraphic units including (if present) surficial aquifers, till confining units, confined/buried aquifers, and underlying bedrock.

Till thicknesses varied from 60 to 166 feet, and till textures ranged from a sandy loam (HFC site) to a silt loam/clay loam (Olivia site). The Cromwell, HFC, and Litchfield 1 sites were examples of “leaky” tills with high vertical hydraulic conductivity (Kv, 0.001 to 1.1 feet per day [ft/d]) and extensive vertical hydraulic connectivity between the confined aquifer and the overlying till. Estimated groundwater travel times through till at these sites ranged from 1 to 81 years, and two of these sites had tritium throughout their till profiles. The tills at the other two sites, Olivia and Litchfield 2, were effective confining units that had low Kv (0.001 to 0.0005 ft/d). Estimated groundwater travel times through the tills at these sites ranged from 165 to nearly 1,800 years, and tritium was only detected in the upper one-third of these till profiles. A conceptual understanding that emerges from the vertical till profiles is that they are not homogeneous hydrostratigraphic units with uniform properties; rather, each vertical sequence is a heterogeneous mixture of glacial sediment with differing abilities to transmit water.

The heuristic MODFLOW modeling demonstrated that, for understanding sustainability of groundwater pumping from confined aquifers, knowledge of till hydraulic properties is just as important as knowledge of aquifer hydraulic properties. Over long periods of time (hundreds of years), pumping-induced hydraulic gradients are established in confined aquifer systems and, even in low hydraulic conductivity tills, these pumping-induced hydraulic gradients increase leakage into and through till compared to ambient conditions.

PROJECT RESULTS USE AND DISSEMINATION

Project results have been and will be disseminated through public presentations and publication of online reports. Results were broadly distributed to hydrology and geology professionals through 13 presentations at state, regional, and national meetings and 2 master’s thesis defense presentations.

Some of these events retain online versions of abstracts and presentations, which are listed below. The full list of presentations about this project is included in the project workplan. Two master's theses are also available online. A series of products from the Minnesota Geological Survey, Minnesota Department of Health, and the USGS provide geologic descriptions, aquifer test analysis results, geochemical data, and model documentation to support the interpretations written in the final, comprehensive USGS Scientific Investigations Report (SIR).

Project Completed: 06/30/2020 **FINAL REPORT**

Assessment of Surface Water Quality With Satellite Sensors

Research Project

Subd. 04i $345,000 TF

Jacques Finlay
U of MN
140 Gortner Lab, 1479 Gortner Avenue
St. Paul, MN 55108
Phone: (612) 624-4672
Email: jfinlay@umn.edu
Web: http://cbs.umn.edu/finlay-lab/home

Appropriation Language
$345,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for a statewide assessment of water quality using new satellite sensors for high frequency measurement of major water quality indicators in lakes and rivers. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Water quality monitoring is essential for managing Minnesota's surface waters, maintaining the services they provide, and detecting changes caused by environmental stressors. Direct measurements of water quality are possible, however, in only a small fraction of the thousands of lakes and river miles in the state. Methods developed in this project allow use of increasingly frequent satellite observations to measure water clarity and the three key water quality indicators that control it: algae, colored dissolved organic matter (CDOM), and suspended solids. Because these parameters have distinct impacts on water quality, the ability to measure them directly across the state's waters enables comprehensive assessment of water quality status and trends and increases understanding of the causes and consequences of water quality degradation. We developed methods to relate direct measurements of water quality to satellite imagery, assessed atmospheric correction techniques and validated methods using independent datasets. We applied these methods to measure water quality parameters on lakes >10ha, and provide the information at https://lakes.rs.umn.edu. Examples are included in appendix 1. Our methods extract information at seasonal to annual scales for algae, CDOM and suspended solids in lakes at state, regional, county, and watershed scales. Water quality parameters were linked to disinfection byproduct formation potential in drinking water treatment and degradation of contaminants driven by sunlight. CDOM levels were closely related to formation rates of two classes of disinfection byproducts, trihalomethanes and haloacetic acids, and to the production photo-induced reactive intermediates that degrade pesticides. This information can be used with remote sensing to assess pesticide persistence and suitability of surface waters for drinking water sources. An ongoing

LCCMR project uses methods developed here with automated imagery acquisition and analysis to gather information on lake conditions at potentially a weekly basis. Project outcomes are summarized at https://water.rs.umn.edu/ for use by researchers, managers, lake associations and the public.

PROJECT RESULTS USE AND DISSEMINATION
Information from this project has been disseminated through five ways during the three year project:

1. Data produced in the project is now freely available at https://lakes.rs.umn.edu/
2. Numerous presentations at meetings, agencies, and academic institutes have been given.
3. Five research articles documenting technical methodology and water quality relationships have been published. These publications have been included in our final report. Several other publications are being developed, and several others are planned.
4. We have engaged with state and agency partners in data gathering and interpretation, resulting in one publication, and plans for future collaborations with MPCA on refining water quality standards in the state based on project findings.
5. A widely used website for remote sensing of water quality (https://water.rs.umn.edu/) has been thoroughly revised with updated and expanded content.

Project Completed: 06/30/2019 **FINAL REPORT**

Water Research Article: Assessment of chlorine demand and disinfection byproduct formation..
Water Research Article: Limitations on using CDOM as proxy for DOC in temperate lakes
Remote Sensing of Enviroment Article: A harmonized image processing workflow using Sentinel-2/MSI and Landsat-8/OLI..
Ecological Application Article: Color, chlorophyll *a*, and suspending solids effects on Secchi depth..
Iron influence on dissolved color in lakes of the Upper Great Lakes States
Brochure: Colored Dissolved Organic Matter in Water
Brochure: Remote Sensning for Water Quality

Development of Innovative Sensor Technologies for Water Monitoring

Research Project

Subd. 04j $509,000 TF

Tianhong Cui
U of MN
111 Church St SE
Minneapolis, MN 55455
Phone: (612) 626-1636
Email: tcui@me.umn.edu

Appropriation Language
$509,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop inexpensive and efficient sensitive sensors and wireless sensor networks for continuous monitoring of contaminants in lakes and rivers in Minnesota. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The University of Minnesota team completed the project successfully by June 30, 2019. Professors Cui, Ruan, and Chen worked with one full-time research assistant, one full-time visiting student, and one post-doc conducting the research. The team finished the proposed research in the proposed Activity 1 and Activity 2. The team developed graphene sensors for testing and continuous monitoring of water quality indicators including phosphate, nitrate, mercury, and chloride. They very successfully got initial testing results using tiny sensors in response to pollutants in lab. They developed software coding for signal process and data display for the small sensing system. They tested the graphene sensors in comparison with the conventional lab tests, and did a compressive assessment of the sensing results. They developed a prototype of sensing network with tiny graphene sensors. The detection limits of the developed graphene sensors for phosphate, nitrate, mercury, and chloride are 0.1 ppm, 0.1 ppm, 1 ppb, and 0.1 ppm, respectively. The response time of the graphene sensors are 10 seconds. The team developed sensing systems and networks for field tests at Mississippi River, Minnesota River, Minnehaha Creek and Bde Maka Ska in Minnesota. The testing results demonstrate the capability of using the graphene sensors and sensing network for real-time monitoring of water pollutants including phosphate, nitrate, mercury, and chloride.

PROJECT RESULTS USE AND DISSEMINATION

On-site demonstration and sensing tests as described in the activities at Mississippi River, Minnesota River, Minnehaha Creek and Bde Maka Ska in Minnesota from May to June, 2019. Communications with interested entrepreneurs have been ongoing with interested parties including local companies and individuals. Collaboration on using the graphene sensors and sensor networks with MPCA and Metro have been conducted in the last year. We use the testing station from MPCA for field tests of pollutants at their Fort Snelling stations in Minnesota River.

Multiple papers were published in archived journals and prestigious conferences. Professor Tianhong Cui presented five invited public seminars and talks on water sensors at: École Normale Supérieure (ENS), Paris, France; Imperial College London, London, UK; Plenary talk, Design, Test, Integration & Packaging of MEMS and MOEMS (DTIP 219), Paris, France; Invited Talk, Microsystems & Nanoengineering Summit, Shanghai, China; Plenary talk, IEEE Nano Conference, Macau.

Project Completed: 06/30/2019 **FINAL REPORT**

Wastewater Treatment Process Improvements

Research Project

Subd. 04k $398,000 TF

Timothy LaPara
U of MN
500 Pillsbury Dr SE
Minneapolis, MN 55455
Phone: (612) 624-6028
Email: lapar001@umn.edu
Web: http://www.ce.umn.edu/people/faculty/lapara/index

Appropriation Language
$398,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to characterize and quantify the nutrient-removing microorganisms used for municipal wastewater

treatment, in order to improve the process used to reduce total nitrogen discharge. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This project included the participation of 25 different wastewater treatment facilities located throughout the State of Minnesota. A total of 623 samples were collected from 38 wastewater treatment bioreactors, from 13 anaerobic digesters, and from 2 aerobic digesters. Metagenomic DNA was extracted and purified from all of these samples and used as template from which we were successfully able to quantify the numbers of total Bacteria, total Archaea, ammonia oxidizing bacteria, ammonia oxidizing archaea, polyphosphate accumulating organisms, denitrifying bacteria, and several different organisms known to be important to anaerobic digestion. DNA samples were also used to amplify and to sequence 16S rRNA gene fragments to characterize the microbial community composition in detail. In total, this project generated 19,064,646 DNA sequences that have been deposited in publicly-available databases. This project demonstrated that wastewater treatment bioreactors and anaerobic digesters generally contain similar levels of total bacteria and archaea, as expected. Substantial differences, however, were observed in the quantity of ammonia oxidizing bacteria, organisms that are critical in the removal of nitrogenous pollution. More importantly, perhaps, is that the quantity of ammonia oxidizing bacteria was connected to specific wastewater treatment process designs, suggesting that the removal of nitrogenous pollution can be controlled. Similarly, the quantity of polyphosphate accumulating organisms varied significantly between different treatment plants. Similar quantities of denitrifying bacteria were observed in all of the wastewater treatment bioreactors, independent of system design; this suggested that denitrifying bacteria are ubiquitous throughout all wastewater treatment bioreactors and their presence/quantity is neither enhanced nor suppressed by system design. This research makes a seminal advance in our understanding of the ecology of wastewater treatment bioreactors by delineating the factors that we can (process design, operating conditions, etc.) and the factors that we cannot (geographic location, weather, etc.) control and their effects on bacterial community composition.

PROJECT RESULTS USE AND DISSEMINATION

We have presented our preliminary results at numerous conferences and technical meetings throughout the State of Minnesota. We will continue to make these presentations over the next 2-5 years (at no cost to the LCCMR). We have published one manuscript in the peer-reviewed literature so far, and we have drafted an additional five manuscripts that have been or will be soon submitted for publication.

Project Completed: 06/30/2019 **FINAL REPORT**

Membrane-Based Process for Decentralized Drinking Water Production

Research Project

Subd. 04l $191,000 TF

Santiago Romero-Vargas Castrillón
U of MN
Department of Civil, Environmental, and Geo- Engineering
Minneapolis, MN 55455
Phone: (612) 301-1347
Email: sromerov@umn.edu

Web: www.cege.umn.edu

Appropriation Language
$191,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a low-energy use, membrane-based treatment technology to produce drinking water locally from surface waters by removing heavy metals and contaminants of emerging concern, including pesticides and pharmaceuticals. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The main outcome of this project is a novel surface modification protocol for water treatment membranes. We showed that graphene oxide coatings, known to exhibit antibacterial properties, improve the efficiency with which the membranes remove micropollutants, such as N-nitrosodimethylamine (NDMA), which are common in Minnesota surface waters. Additional outcomes of this project were promotion of Minnesota's human capital through training of graduate and undergraduate students (2 graduate and one undergraduate student where supported at various points of the project), a M. S. thesis completed by Henry Croll (one of the graduate students supported by the project), a conference presentation (at the Annual Meeting of the American Institute of Chemical Engineers, AIChE 2017), and a recent publication in Separation and Purification Technology, a peer-reviewed international journal.

PROJECT RESULTS USE AND DISSEMINATION

This project accomplished the following dissemination outcomes:

Pee-reviewed publications (1): H. Croll, A. Soroush, M. Pillsbury, and SRVC. "Graphene oxide surface modification of polyamide reverse osmosis membranes for improved N-nitrosodimethylamine (NDMA) removal". Separation and Purification Technology 210 (2019) 973–980

The article is available from the following link without a subscription until November 2, 2018: https://authors.elsevier.com/a/1XjGX4wbrSvhOh

Conference papers (1): A. Soroush, H. Croll, and SRVC. "N-Nitrosodimethylamine (NDMA) Removal by Thin Film Composite Polyamide Reverse Osmosis Membranes". 2017 AIChE National Meeting, Minneapolis, MN. November 1st, 2017.

Dissertations (1): H. Croll. "Improvements to Polyamide Reverse Osmosis Membranes for Removal of Small, Uncharged, Hydrophilic Solutes". MS Thesis, University of Minnesota, 2018 (available from the UMN Libraries).

Project Completed: 06/30/2019 **FINAL REPORT**

Separation and Purification Technology: Publication

Analyzing Alternative for Muncipal Wastewater Treatment

Subd. 04m $180,000 TF

Scott Kyser
Minnesota Pollution Control Agency
520 Lafayette Rd
St. Paul, MN 55155

Phone: (651) 757-2665
Email: scott.kyser@state.mn.us
Web: https://www.pca.state.mn.us/water/protecting-wild-rice-waters

Appropriation Language
$180,000 the second year is from the trust fund to the commissioner of the Minnesota Pollution Control Agency to analyze alternatives for improved treatment of sulfate and salty parameters at municipal wastewater plants to inform the development and implementation of wild rice, sulfate, and other water quality standards. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

A future surface water quality standard for sulfate may result in some municipal wastewater treatment plants having to reduce the sulfate in their discharge. This study evaluated options for sulfate treatment and examined the implications of those treatment options for typical municipal wastewater treatment plants in Minnesota. This study's findings gives regulatory agencies and MN communities' greater certainty of the cost of any future sulfate treatment technologies. This information will be used to guide the MPCA's future wild rice rulemaking efforts. 31 technologies for sulfate removal were ranked based on effectiveness, operability, cost, complexity of pre- and post-treatment, and waste management requirements. The types of technologies reviewed included chemical precipitation, ion exchange, membrane separation, electrochemical, biological, and evaporative treatment. The technology review indicated that reverse osmosis is the most well developed and effective alternatives available for sulfate removal at this time, despite the complexity and cost associated with final waste management. The study examined the implementation of RO for sulfate removal at Minnesota's municipal wastewater treatment plants in greater depth, using six hypothetical case studies covering a range of treatment plant sizes and sulfate treatment goals typical for the state. The case studies considered the technical, operational, and economic issues associated with integration of RO into conventional municipal treatment systems. Sulfate treatment using RO was found to be extremely expensive and operationally complex. The main driver of complexity and costs was membrane waste management, which in this study focused on mechanical evaporation and crystallization. Due to the complexity of the processes, which differ significantly from those currently employed for conventional municipal wastewater treatment, increased staffing levels and operator training would be needed for successful implementation. RO is effective in removing sulfate from wastewater, but waste management challenges remain a substantial barrier to implementation and affordability.

PROJECT RESULTS USE AND DISSEMINATION

The results of this study were disseminated through two presentations at a Minnesota wastewater treatment conference and two presentations at a national conference for city engineers. The results of the study were incorporated into the proposed wild rice sulfate rulemaking documents and used to inform testimony by the MPCA before both the Minnesota house and senate.

The final report, a one page summary of the report and a recorded video of the final results presentation is available on the MPCA webpage: https://www.pca.state.mn.us/water/protecting-wild-rice-waters

Project Completed: 06/30/2019 **FINAL REPORT**

MPCA Fact Sheet - Sulfate and municipal wastewater: Study confirms lack of affordable technology
Analyzing Alternatives for Sulfate Treatment in Municipal Wastewater

Understanding Impacts of Salt Usage on Minnesota Lakes, Rivers, and Groundwater

Research Project

Subd. 04n $497,000 TF

John Gulliver
U of MN
2 Third Ave SE
Minneapolis, MN 55414
Phone: (612) 625-4080
Email: gulli003@umn.edu

Appropriation Language
$497,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to quantify the current water-softening salt loads in Minnesota lakes, rivers, and groundwater, assess alternative water-softening materials and methods, and quantify the transport of de-icing and water-softening salt through the soil. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Increasing chloride levels in surface waters and groundwater are an emerging concern in Minnesota, as they can negatively impact aquatic and plant life. This project developed two new chloride mass budgets: a wastewater treatment plant (WWTP) chloride budget and a statewide chloride budget. The results of the WWTP chloride budget accounted for 98% of the chloride discharged from included WWTPs and showed that water softener use was the largest chloride point source investigated in the WWTP chloride budget. At the statewide level, household and commercial water softening were estimated to contribute 65% of WWTP chloride discharge. Industries were also major sources, contributing 22% of the estimated chloride load of statewide WWTPs. In the statewide chloride budget, road salt use was the largest chloride source, contributing 403,600 metric tons (t) of chloride annually to surface waters. Chloride from fertilizer use was the next largest chloride source (221,300 t), followed by WWTPs (209,900 t), livestock waste (62,600 t) and residential septic systems (33,100 t). The results of the statewide chloride budget show that water softeners are major sources of chloride and indicate that increasing efficiency of water softener salt use could be a viable strategy to manage chloride levels in wastewater and receiving waters.

Column experiments and analysis of field soil cores were performed on soils common in Minnesota: silt loam, sandy loam, and sandy loam with 10% organic material. Analysis of these indicate that chloride is sometimes stored within the soil and is released at other times, likely due to storage in capillary spaces and anion exchange and/or adsorption. Thus, a long period of freshwater rinse (tens to hundreds of years) is required to fully remove chloride from soils in Minnesota and chloride in our groundwater will be a legacy for some time.

PROJECT RESULTS USE AND DISSEMINATION

The results of this project were disseminated throughout the project via presentations, workshops, listening sessions, interviews, surveys, emails, and webinars, among others. The first list of dissemination efforts is provided in the final work plan update for the project. In addition, fact sheets and final project reports were developed and are provided with the final status update for the project and online.

Project Completed: 06/30/2019 **FINAL REPORT**

Reducing salt and metal removal costs with microbes

Research Project

Subd. 04o $596,000 TF

Daniel Bond
U of MN
140 Gortner Laboratory
1479 Gortner Ave
St. Paul, MN 55108
Phone: (612) 624-8619
Email: dbond@umn.edu

Appropriation Language
$596,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to continue to research the potential of recently discovered microbes from Soudan Iron Mine in northern Minnesota for removing salts and metals from groundwater and surface water resources. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Many Minnesota waters are contaminated with salts and metals. Removing these contaminants can be more difficult than removal of compounds such as oils or pharmaceuticals which can be destroyed by bacteria or heat treatment. Metals and salts must be physically bound, or made to pass through a specific membrane to clean the water, making such treatments expensive and energy intensive. However, technologies have been proposed that use microorganisms as the power source to drive salts across membranes, or as binding agents to remove metals, significantly reducing the cost and complexity of treatment. Before such technologies can even be imagined at scale, naturally-occurring microorganisms that are tolerant of harsh conditions and able to power removal of salts from water must be made available. A key goal of this project was to discover such organisms, subject them to the stresses of life under the conditions, and understand what could limit implementation of these remediation strategies. After surveying a number of contaminated sites in Minnesota, we focused specifically on the power-generating abilities of bacteria related to the genus Geobacter, the salt-tolerance abilities of bacteria related to the genus Marinobacter, and the metal transforming abilities of fungal Armilleria and Periconia genera. We verified that these organisms can grow in high salt conditions, power model salt-removal reactors, and in some cases remove multiple metals from solution. In the case of salt removal, we showed that many of the operating conditions proposed, such as cycling of the cell voltage or operation at low redox potential, can be harmful to cells and will need to be addressed before the technology can be successful, as will issues related to high calcium content of some Minnesota waters. In contrast, because the use of fungi for metal removal does not require as much equipment or electrochemical control, scaling of this approach using organisms obtained via this project is deemed much more feasible.

PROJECT RESULTS USE AND DISSEMINATION

Our primary scientific dissemination activities are manuscripts crediting this project, two of which are under revision or submission and not available online at the time of this report. We presented our

results at the 2nd Geobiology Society Conference in Banff, Canada, in June 2019 in the poster section titled as “Remediation of Metals by Mn-Oxidizing Fungi in Minnesota Soudan Iron Mine”. Other examples of local exposure include also the Mycological Society of America 2019 Annual Meeting in Minneapolis, MN, in August 2019. In October, the research results will be presented at the Society for Mining Engineers conference in Minneapolis, MN.

As part of this project we conducted outreach activities to show the potential offered by bacteria powering salt-removal devices. Some examples of outreach during this project include: three ‘Market Science’ events, bringing demonstration devices to farmer’s markets in the Twin Cities area, three events as part of the Bell Museum’s 3rd and 4th-grade science camps where students constructed microbial powered devices and meet scientists in our laboratory, assisting two local Lego League teams who were incorporating microbial power into their demonstration projects and providing materials for their devices (one group progressed to the State competition), hosting a short workshop training graduate students in construction of microbial electrochemical devices, participation in the MN clean water summit and the American Society for Microbiology science outreach series. Our other stated goal was to facilitate group meetings with other collaborators and interested parties so this work could expand or continue. Due to these collaborations, work initiated in this project in terms of searching for new organisms from metal-impacted environments will be able to continue in a 5-year NSF-funded project to be based in the Soudan Mine, fulfilling a key goal described in our Long Term Strategy. We have also applied for new support from other state-based programs (such as MNDrive) to support the scale-up of new technologies for bioremediation.

We will continue to share these results, including demonstration experiments about bioremediation strategy use the type 1 bioreactor to general audiences on August 22nd, 2019 at the Minnesota State Fair with Market Science. Further, these type 1 bioreactors will now be regularly prepared for Sound Underground Mine State Park science tours of the mine. Mine tour guides will demonstrate these at the mine, and the cultures have been shared for observation under a microscope in collaboration with State Park staff.

Project Completed: 06/30/2019 **FINAL REPORT**

Engineered Biofilter for Sulfate and Metal Removal from Mine Waters

Research Project

Subd. 04p $440,000 TF

Sebastian Behrens
U of MN
500 Pillsbury Dr SE
Minneapolis, MN 55455
Phone: (651) 756-9359
Email: sbehrens@umn.edu
Web: http://www.cege.umn.edu/directory/faculty-directory/behrens.html

Appropriation Language
$440,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop an efficient, low-cost, biomass-derived adsorbent material for use in bioactive filters able to remove sulfate and metals from mining-impacted waters. This appropriation is subject to Minnesota

Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Biochar is a stabilized, recalcitrant organic carbon material, created from biomass heated to temperatures between 300-1000°C, under low oxygen concentrations. Biochars can be produced from a variety of biomass feedstocks. Recently, biochars have found several applications in environmental remediation of heavy metals contamination. In this project we compared the sorptive properties of different biochars for soluble copper (Cu2+) and nickel (Ni2+) removal from contaminated waters. In order to enhance the sorptive properties of biochars, we pyrolyzed hardwood biomass in the presence of magnesium hydroxide or magnesium chloride. Using the newly produced biochar-composite material we compared its sorption isotherms for copper and nickel with an unmodified biochar. Copper and nickel sorption capacities were greatly improved for the biochars pyrolyzed in the presence of magnesium salts, indicating that biochar mineral supplementation can increase the efficiency of metal adsorption and removal from solution. Scanning electron microscopy (SEM) coupled to energy dispersive X-ray spectroscopy (EDS) revealed strong surface localization of both copper and nickel after sorption onto magnesium hydroxide treated biochar, with a lesser extent of copper surface localization on magnesium chloride than magnesium hydroxide treated biochar. A subsequent study was conducted to test the effects of post-pyrolysis mineral modification (added as soluble Mg) on unmodified biochar's sorption capacity for heavy metals. This part of the project revealed that metal-mineral surface complexation, rather than covalent modification, was the major driver for enhancing copper sorption in treatments amended with either magnesium hydroxide or magnesium chloride. However, similar effects were not observed for nickel sorption. In this project we develop a biochar-mineral composite material that promotes heavy metal adsorption. The new sorbent material made from waste biomass is an efficient, low-cost, environmentally-friendly alternative to conventional sorbent materials that can be used for mine water treatment in water filters or permeable reactive barriers.

PROJECT RESULTS USE AND DISSEMINATION

Three peer-reviewed manuscripts are expected to be published from this work; these will be submitted to the LCCMR when accepted for publication. Multiple presentations about the research have been given at both regional and national/international conferences.

Project Completed: 06/30/2019 **FINAL REPORT**

Developing Biosponge Technology for Removal of Nitrates from Minnesota Waters

Research Project

Subd. 04q $198,000 TF

Lawrence Wackett
U of MN
1479 Gortner Ave
St. Paul, MN 55108
Phone: (612) 625-3785
Email: wacke003@umn.edu

Appropriation Language
$198,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to adapt and test an inexpensive biosponge technology for its effectiveness at removing nitrates from

drinking water. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

We have developed simple, effective, and inexpensive technology for dealing with nitrate in drinking water, a major problem in Minnesota today. The cost of continuous monitoring and treating nitrate problems with current technology is estimated to be $3500 per household, a huge burden for Minnesotans. To help in alleviating that burden, we have done the following on this project. First, the project director, Dr. Aukema, identified nitrate-removing bio-components. Second, Dr. Aukema investigated and was successful in obtaining different sponge-like materials to maintain the bio-components within the material. Third, water from different sites in the state of Minnesota were obtained and tested with respect to nitrate. The waters were from: Montevideo, Lake Itasca, St. Paul, Zumbro Falls, and Minneapolis. Much work went into designing the matrix that holds the bio-component. It was found that cellulose was best for retaining the bio-component. The bio-component will then reduce the nitrate which is then both measured and removed. The last year of the project was devoted to outreach, disseminating the information: (1) verbally at conference, agencies, universities, (2) in written form in a journal publication, and (3) by the social media platform YouTube. Overall, we conducted outreach over the course of the project, discussing nitrate treatment entirely in, or as part of, 14 outreach items, in Minnesota, other states, and internationally. Note that any and all travel was covered by resources outside of the LCCMR budget. This is important to Minnesotans as it provides a way to cheaply and easily monitor nitrate in any water source they would want, from their local lake to their well. This also provides information for bioremediation of nitrate and other chemicals that are found in Minnesota waters. While generally chemical levels in Minnesota are low, we are glad to develop technology to help in keeping our waters clean.

PROJECT RESULTS USE AND DISSEMINATION

We have conducted dissemination activities throughout the project, with the last year of the project being heavily engaged in that activity specifically. For example, we presided over an event at the Institute on the Environment at the University of Minnesota on March, 2019 to discuss and disseminate information dealing with nitrogen and nitrate contamination in Minnesota waters and how to deal with it effectively. We followed that up with a broader meeting on May 16, 2019. In the last year of the project, we also published a research article pertaining to new technology developed. We also posted a YouTube video.

Project Completed: 06/30/2019 **FINAL REPORT**

Morrison County Performance Drainage and Hydrology Management

Subd. 04r $209,000 TF

Helen McLennan
Morrison SWCD
16776 Heron Rd
Little Falls, MN 56345
Phone: (320) 616-2479
Email: helen.mclennan@mn.nacdnet.net

Appropriation Language
$209,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Morrison Soil and Water Conservation District to conduct an assessment of drainage infrastructure, in order to develop hydrology restoration priorities and a countywide performance drainage ordinance to address land use-change impacts to the hydrogeology. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Morrison County, like other agricultural counties, has experienced a vast increase in drainage. Thousands of acres are being tiled with no approval or oversight and wet weather patterns have exacerbated drainage issues along township and county roads. Major conflicts have exploded between neighbors and road authorities' due to impacts of standing water on agricultural fields and topping of public roads.

Morrison SWCD historically has taken the lead in managing drainage, county wide, and starting in 2016 centerline and driveway culverts were surveyed to better comprehend the hydrology and storm water management for the county. Morrison SWCD documented locations, elevations and conditions of culverts throughout 23 townships in Morrison County. The complete database of this information was shared with each township and Morrison County Public Works department for a more complete understanding of drainage capacity and infrastructure replacement needs. In addition to being used by Morrison SWCD to resolve landowner conflicts, watershed and wetland protection, it is also being used by other state and federal for water quality protection and enhancement, identifying wildlife project areas and for floodplain mapping. Limited database information is available for public viewing through the Morrison County interactive GIS viewer, Beacon.

This information has led to the creation of a Morrison County Comprehensive Drainage Management Plan. This plan was created to protect state water resources from runoff pollution and degraded water quality, stabilize soils, shores and banks from erosion, protect or provide riparian corridors and preserve natural drainage ways and wetlands from being drained filled and manipulated.

Morrison SWCD is committed to serving the public through a leadership role in managing drainage and sharing a more complete understanding of drainage infrastructure within the county and with other areas of the state struggling with drainage issues.

PROJECT RESULTS USE AND DISSEMINATION

Reports of the culvert inventory data were finished and delivered to 23 townships. These reports included locations and elevation data for centerline and private drive culverts along township roads. The reports also detailed material size, type, shape and conditions of pipes and flow direction. Culverts were then rated based on their current conditions and recommended maintenance activities were noted.

We are continuing to keep all the partner agencies up to data with our data and progress, attending township and county board meetings and presenting the information to our partners. A subset of the data from the inventory was made available for public viewing on the Morrison County interactive GIS system, Beacon. Full data sets were shared with FEMA, DNR, Morrison County Public Works and US Fish and Wildlife Service.

LIDAR assessment of minor watersheds was done as data became available to determine drainage capacity and identify insufficient patterns. The number of requests made to the office for drainage assistance by Morrison County and township officials has significantly increased since the start of the

project many long standing issues were able to be resolved with the use of the culvert inventory data and the field expertise of the drainage technician afforded through this grant.

Discussions continue with county officials regarding a drainage ordinance which was drafted as part of this project. The Morrison County Comprehensive Drainage Management Plan was created to protect state water resources from runoff pollution and degraded water quality, stabilize soils, shores and banks from erosion, protect or provide riparian corridors and preserve natural drainage ways and wetlands from being drained filled and manipulated.

Project Completed: 06/30/2019 **FINAL REPORT**

Assessing Effectiveness of Wetland Restorations for Improved Water Quality - RESEARCH

Subd. 04u $420,000 TF

Jacques Finlay
U of MN
1987 Upper Buford Cir, 404 Ecology Bldg
St. Paul, MN 55108
Phone: (612) 624-4672
Email: jfinlay@umn.edu
Web: http://www.cbs.umn.edu/lab/finlay

Appropriation Language
$420,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to quantify the environmental benefits of sediment removal and native plant communities in wetland restorations by measuring resulting reductions in nitrogen and phosphorus delivery to groundwater and surface water. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Wetland restorations are vital for enhancing habitat and protecting against growing threats from eutrophication to Minnesota's drinking and recreational waters. Using comparisons of standard wetland restoration practices with those that also removed accumulated sediment, we examined outcomes of restorations across gradients of wetland size, age, and hydrology. Our goal was to investigate the effects of 1) excavating accumulated eroded sediment, 2) time since restoration, and 3) hydrology, on the ability to store and remove nutrient input from the watershed over time, and on the abundance and diversity of native and invasive vegetation in restored wetlands. We studied 58 restored agricultural wetlands, collecting over 1000 water, 800 soil, and 258 plant samples over three years. Substantial water quality improvements resulted from both standard and sediment removal treatments. Excavation reduced total nitrogen (N) and total phosphorus (P) in soil and surface water, although the strength of effects varied substantially by nutrient and wetland type. In general, soil and water nutrient content increased with wetland age since restoration, suggesting that wetlands effectively stored incoming nutrients. Restored wetlands overall had a high capacity to remove nitrate under a wide range of temperature, age, size and geomorphic conditions, resulting in extremely low concentrations of nitrate. Permanent N removal via denitrification did not differ between excavated and standard restoration practices, but seasonally flooded wetlands had significantly higher denitrification rates than semi-permanent basins that dry out much less frequently. N removal by denitrification increased steadily following restoration, indicating improved capacity for nitrate reduction in older wetlands. In contrast to

nitrogen, seasonal flooding promoted mobilization of inorganic phosphorus to surface waters, suggesting effects of long term enrichment of phosphorus in watershed soils. Vegetation accounted for a substantial portion of N and P stored in wetland basins during the growing season, with invasive hybrid cattail containing over 70% of the N and P stored in plant biomass. Following restoration, excavated wetlands had significantly lower hybrid cattail cover and higher native species cover compared to wetlands restored without sediment removal. However, rapid expansion by hybrid cattail offset vegetation benefits of sediment removal within eight years following restoration. Our study demonstrated that sediment excavation promotes native species and at the same time, reduces nutrient availability and improves water quality in restored agricultural wetlands. Environmental factors such as basin inundation patterns and time since restoration influence the ability of wetlands to perform key services. Eutrophication is a growing threat to Minnesota's drinking and recreational waters, and our work showed that agricultural wetland restorations can substantially reduce the risk of eutrophication. Benefits of wetland restoration can be maximized by removing accumulated sediment during restoration and managing invasive species in the years following restoration.

PROJECT RESULTS USE AND DISSEMINATION

Information from this project has been used and disseminated in diverse ways during the three year project. Results from the project have been presented at national, regional, and state meetings and events including; the Society for Freshwater Sciences annual conference (May 2019), the Society for Wetland Sciences annual conference (May 2019), the Minnesota Chapter of the Wildlife Society annual conference (February 2017 and February 2018), the joint meeting of the Upper Midwest Invasive Species Conference and North American Invasive Species Management Association (October 2018), and a meeting of Minnesota private lands managers and conservation specialists including The Nature Conservancy, the US Fish and Wildlife Service, Minnesota Department of Natural Resources, Minnesota Land Trust, Ducks Unlimited, and the U.S. Department of Agriculture (June 2018). We have shared our research with local entities including the University of Minnesota's Shared Water, Shared Responsibility: Engaging Minnesota's Communities, Students, & Policy-Makers event (March 2017), the Water Resources Science Spring Research Symposium (January 2018), the Pomme de Terre Watershed Task Force (May 2018), Restoration Evaluation Specialists at the Minnesota DNR Division of Ecological and Water Resources (March 2018), and The Nature Conservancy (August 2018), and we continue to reach out to other stakeholders and land management groups to share the results of our research. Furthermore, the results from this research have been shared regularly with the US Fish and Wildlife Service Private Lands Office and restoration specialists working with landowners across the state. We have submitted one manuscript addressing the effects of sediment excavation on plant communities to the journal Restoration Ecology (submitted July 2018) and another manuscript to the journal Wetlands. In addition, two more manuscripts are in preparation, and others are planned. Copies of the manuscripts will be provided upon publication. Finally, we have developed a set of interactive tools to start conversations about wetlands with children and adults. Using visual aids, hands-on activities, and informational handouts, we were able to reach hundreds of people in the summer of 2018 at the West Ottertail County Fair and the Fergus Falls Aqua Chautauqua, by focusing on exploration and discovery in our backyard wetlands. Our activities and handouts are still being used by environmental and K-12 educators in the Ottertail Public School District. Appendix 2 provides examples of our outreach materials.

Project Completed: 06/30/2019 **FINAL REPORT**

Integrating Targeted Watershed Planning Tools with Citizen Involvement

Research Project

Subd. 04v $169,000 TF

Kimberly Musser
Minnesota State University - Mankato
Water Resources Center
135 Trafton Science Center S
Mankato, MN 56003
Phone: (507) 389-5492
Email: kimberly.musser@mnsu.edu
Web: http://cset.mnsu.edu/wrc/

Appropriation Language
$169,000 the second year is from the trust fund to the Board of Trustees of the Minnesota State Colleges and Universities system for the Water Resources Center at Minnesota State University, Mankato, to use geographic information system (GIS) prioritization and modeling tools to develop pollution reduction strategies in five priority subwatersheds in the Le Sueur River watershed and to promote implementation of the reduction strategies through citizen involvement and outreach. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Le Sueur River Watershed (LSRW) is one of the leading contributors of pollutant loads in the Upper Mississippi River Basin. The 711,000 acre watershed is a listed as a priority watershed for both nitrogen and phosphorus in the Minnesota Nutrient Reduction Strategy and is a prolific source of total suspended solids which impacts downstream receiving waters from the Minnesota River to the Gulf of Mexico. The project goals were to use geographic information system (GIS) prioritization and modeling tools to develop pollution reduction strategies in five priority subwatersheds in the LSRW and to promote implementation of the reduction strategies through citizen involvement and outreach.

The project resulted an inventory handbook of GIS conservation planning and targeting tools to help local conservation partners better understand the diversity of available tools (link). A statewide survey of GIS tool users was also developed and summarized (link). Five subwatershed strategies were developed by citizens and conservation partners that illustrate conservation opportunities based on the latest targeting tool outputs, maps and citizen input (link). The project harnessed the energy of a citizen group, the LSRW Network to facilitate improvements in one of the most degraded watersheds in the state.

More broadly, this project demonstrates subwatershed scale planning that uses GIS conservation targeting tools integrated with civic engagement—a promising approach and scale for nonpoint source pollution clean-up. The project underscores the power of conservation partners engaging community members around locally relevant problem solving that aligns with existing social networks. Subwatershed groups learned and adapted together while citizen leaders networked with peers, building strong relationships and enduring partnerships. The project also raised awareness statewide about the need to re-create more water storage across the Minnesota River Basin to reduce peak flows that are destabilizing river systems and contributing to water quality problems (Water Storage Forum).

PROJECT RESULTS USE AND DISSEMINATION

Information about this project is housed on the Le Sueur River Watershed Network and the Minnesota River Basin Data Center websites. Project reports include an inventory handbook of GIS conservation

planning and targeting tools to help local conservation partners better understand the diversity of available tools (link). A statewide survey of GIS tool users was also developed and summarized (link). Five Subwatershed Strategy documents were created (link) that integrate GIS conservation targeting with citizen engagement. Information about Le Sueur River Watershed and priority subwatersheds are summarized on the Le Sueur River Watershed Network and MRBDC websites.

The project has resulted in hundreds of one-on-one, small and large group meetings to disseminate information with citizens and conservation partners at subwatershed, watershed, and basin scales. Project staff had the opportunity to share information about the project at international, national, state, regional and local conferences and meetings. International and national highlights include audio interviews housed at the Museum on Mainstreet, Smithsonian Institute, a presentation at the Soil and Water Conservation Society International Conference in Madison WI; presentations at the Watershed Leaders Network Meeting, Hannibal, Missouri and Dubuque, IA. Statewide highlights include Governor's Water Quality Town Hall Meeting, numerous presentations at Minnesota Water Resources Conferences.

Project staff have made over a dozen presentations and hosted tours regionally and locally to raise awareness about the project and outcomes ranging from local and regional government (County, SWCD, GBERBA), to state and elected officials (Minnesota Legislative Water Commission, Clean Water Council, Governor's Office) to conservation groups (Minnesota River Congress, Friends of Minnesota Valley, Izaak Walton League, Clean Water Minnesota). A project highlight was raising the awareness about the need for more water storage statewide by developing and hosting the Minnesota River Basin Water Storage Forum and website. During the project period, dissemination through media outlets include over 20 newspaper articles, four KEYC television interviews, and three nationally publicized audio interviews. In addition, project partners created the Le Sueur River Watershed Network website, created four videos, as well as numerous posters and summary maps and other public informational materials.

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 05 Environmental Education

Minnesota Conservation Apprentice Academy

Subd. 05a $433,000 TF

Jenny Gieseke
Board of Water and Soil Resources
520 Lafayette Rd
St. Paul, MN 55155
Phone: (507) 381-3131
Email: jenny.gieseke@state.mn.us
Web: http://www.bwsr.state.mn.us

Appropriation Language
$433,000 the second year is from the trust fund to the Board of Water and Soil Resources in cooperation with Conservation Corps Minnesota and Iowa for the final phase of a program to train and mentor future conservation professionals by providing apprenticeship service opportunities with local soil and water conservation districts in Minnesota. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Minnesota Conservation Apprentice Academy was designed to provide a mechanism for maintaining an experienced conservation workforce in Minnesota despite the recent wave of retirements that have occurred as baby-boomers leave the workforce. As these experienced conservation professionals retire, they take with them their practical, on-the-ground experience and skills. While college students may have knowledge of emerging technologies and other innovations that can improve and contribute to current conservation efforts, they often lack experience with on the ground projects and relating to landowners. The Conservation Apprenticeship Academy filled this gap by providing an opportunity for the two generations to exchange knowledge during the SWCD's busiest season.

This project funded the placement of 31 apprentices in 2017 and 33 apprentices in 2018. Over the course of the grant period, these 64 young adults gained skills and experience in water resource management, conservation inspections, surveying and habitat restoration.

The program had a mutually beneficial impact on both the students and the SWCDs they were placed in. 100% of the SWCDs that participated in the project indicated they would partner with the program again. SWCD staff noted that Apprentices added value to project work through their knowledge and skills while also becoming better prepared for future careers. Apprentices who responded to a survey request all indicated they felt more prepared for a future career in conservation as a result of the program.

PROJECT RESULTS USE AND DISSEMINATION

Information from this project has been disseminated through reports to LCCMR, information on the Conservation Corps website, blog posts, and in a Conservation Conversation podcast.

Conservation Corps provides a description of the program on the organization's website (updated in October 2018 to indicate the completion of the program as funded by LCCMR).

Additional coverage over the course of the project includes: 2017 Apprentice featured on Conservation Corps blog, 2017 Apprentice featured on KLQP "Conservation Conversation" podcast, 2017 Apprentice featured on Conservation Corps blog, and coverage of the project in the Austin Daily Herald.

Project Completed: 06/30/2019 **FINAL REPORT**

School Forests Outdoor Classrooms

Subd. 05b $440,000 TF

Amy Kay Kerber
MN DNR
500 Lafayette Rd
St. Paul, MN 55155
Phone: (651) 259-5263
Email: amykay.kerber@state.mn.us
Web: http://www.mndnr.gov/schoolforest

Appropriation Language
$440,000 the second year is from the trust fund to the commissioner of natural resources in cooperation with Conservation Corps Minnesota and Iowa to renovate and restore 60 school forests and train students, teachers, school district facility staff, and community volunteers to be long-term stewards of the school forests and provide education and service learning experiences at school forest sites. This

appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Minnesota Department of Natural Resources worked with the Conservation Corp of Minnesota and Iowa to improve 67 School Forests throughout Minnesota, completing land management projects that schools were unable to do on their own. The work improved the safety, accessibility, and effectiveness of School Forests, making them better outdoor classrooms. DNR and CCMI staff worked with school leaders to identify needed projects that aligned with their existing School Forest Stewardship Plan, secure school contributions for materials, and complete all work. Efforts included repair of unsafe structures, removal of hazard trees and invasive species, building and maintenance of trails, and construction of amphitheaters, sitting spaces, boardwalks, and bridges. Project highlights can be found in attachments C, D, E, and F to the final report.

School communities were involved in all work. Over 3,300 students participated in service learning activities tied to the work projects done at their School Forest. To support long-term site maintenance, 412 school staff and community volunteers were trained to care for their School Forests.

At these newly improved School Forests, students will continue to learn math, science, art, social students and more for decades to come. These learning experiences connect students to their natural surroundings and provide hands-on, real-world experiences for Minnesota students. School staff and community volunteers have a renewed interest in using and increased confidence in maintaining the sites. They also report that these projects have enriched learning experiences, and bolstered relationships between students, staff, and their School Forest. Students enjoyed participating in the projects and have an increased sense of ownership.

This project furthered our knowledge of what elements make effective outdoor classrooms that support long-term outdoor education for Minnesota schools.

PROJECT RESULTS USE AND DISSEMINATION

The School Forests Outdoor Classrooms Project was featured in many newspaper articles, TV news stories, and school newsletters throughout Minnesota, such as a Lakeland Public Television story on the Dean Makey School Forest buckthorn removal project. The Pine River-Backus School Forest project was featured multiple times in their local news media, including a Lakeland Public Television story "Pine River-Backus Students Remove Buckthorn," and an article "Pine River-Backus School Board Revisits Buckthorn" featured in the PineandLakes Echo Journal. The Edgewood School Forest project and DNR School Forest Program were highlighted in a video created by the Mounds View School District titled "Edgewood School Forest Project" that was shared widely throughout the district via e-newsletters and social media. The Clearview Elementary School Forest project was featured in the local newspaper, Citizen-Tribune, with an article titled “Clearview Forest Gains a Handicapped Accessible Trail.” The Hutchinson School Forest service learning and invasive species education activities at Rollie Johnson Ecological Site project were featured in the Hutchinson Leader. Additionally, Lake Minnetonka Magazine printed an article in the Outdoors section about the 2018 St. David’s School Forest CCM project.

The DNR posted 62 tweets resulting in 54,615 impressions, 85 retweets, 346 likes, and 1,249 media views and engagements. Many schools and partners also tweeted or posted to Facebook. In 2016, the Minnesota Lottery created a short video about this ENRTF project that was shared by the Lottery during an event at the Mall of America and on its online blog.

Project findings have been shared with School Forest teachers and volunteers at School Forest conferences, summits, and regional trainings. Project learnings and evaluation results have been shared

with DNR field foresters to help improve their relationships and serves provided to local School Forest sites. Additionally, project evaluation results relating to how best to support teachers in outdoor classrooms will be shared with environmental educators through regional and state conferences and meetings.

Project Completed: 06/30/2019 **FINAL REPORT**

New Prairie Sportsman Statewide Broadcast Video Project

Subd. 05d $300,000 TF

Cindy Dorn
Pioneer Public Television
One Pioneer Drive
Granite Falls, MN 56241
Phone: (651) 230-3995
Email: cdorn@pioneer.org
Web: http://prairiesportsman.org/

Appropriation Language
$300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Pioneer Public Television to provide outreach on outdoor recreation, conservation, and natural resource issues, including water quality, wildlife habitat, and invasive species, through a series of interrelated public forums, educational and training videos, and statewide broadcast television programs. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Prairie Sportsman celebrates our love of the outdoors and connecting to Minnesota's vast resources of lakes, rivers, trails and grasslands. As Pioneer Public Television's most popular production, the show had been on hiatus for five years until the Minnesota Environment and Natural Resources Trust Fund enabled Pioneer to produce 26 new episodes for the 2017-18 seasons.

Prairie Sportsman increased its focus on natural resource protections needed to preserve access to outdoor recreation and widened its appeal to a diverse, statewide audience. As a result, all six Minnesota Public Television Association members aired the 2018 season. This project has provided engaging environmental science education, increased awareness of environmental issues and provided ways for individuals, communities and organizations to restore and protect natural resources.

The 26 episodes including two live town hall broadcasts, 24 environmental science and conservation segments and 26 aquatic invasive species minutes, along with sports, recreation, outdoor lifestyle and audience Q&A segments.

Conservation segments featured topics such as strip tilling to reduce soil erosion, conducting burns to restore natural habitats, genetically diversifying purebred bison herds, evaluating beaver impacts on trout streams, using bioreactors to remove nitrates from farm drainage water, growing camelina and other cover crops, controlling buckthorn with goats, restoring prairie chicken and sandhill crane populations and tagging Monarchs for research. Every episode also included a video short on preventing the spread of aquatic invasive species with a "clean, drain, dry" message.

The Prairie Sportsman website, blog and social media have significantly increased the program's reach. For example, a Mallard research segment uploaded to Facebook reached over 53,000 people with 114 shares; a Monarch tagging segment reached 11,734 with 83 shares. Through broadcast television and digital media, Prairie Sportsman invested ENRTF funds in content that inspires Minnesotans to connect with the outdoors and protect precious natural resources.

PROJECT RESULTS USE AND DISSEMINATION

Prairie Sportsman has achieved statewide appeal and is now aired on all Minnesota Public Television stations, including KSMQ Austin, Lakeland Public TV Bemidji and Brainerd, WDSE Duluth, Prairie Public TV Fargo and TPT MN as well as Pioneer Public TV. Episodes are also widely viewed online at http://prairiesportsman.org/ , https://video.pioneer.org/ and Facebook.

In addition, each episode's three 6 to 12 minute video features and AIS video shorts are segmented and individually branded to stand alone. They are offered to all who participated in the segment to use for their own public outreach and education purposes. For example, the Riverside History & Nature Learning Center in New Ulm is showing a segment on Riverside at the center; Pheasants Forever chapters have aired pheasant hunting and habitat research segments at banquets; a segment on Fort Ridgely Equestrian Center endurance riders aired at the Horse Expo; SWCD Aquatic Invasive Species Task Forces are using segments for public education and outreach.

The segments are also promoted heavily on social media, with demonstrated results. Prairie Sportsman's digital space has had phenomenal growth, highlighted by a segment on Mallard tagging and research that was uploaded to Facebook and organically reached over 53,000 people with 613 reactions, comments and shares and a total watch time of 11,000 minutes. This was more than six months after the segment's air date of February 18, 2018, demonstrating how social media can extend the life and reach of "evergreen" Prairie Sportsman programs and increase the effectiveness of ENRTF funding in bringing educational videos to a statewide audience.

Facebook has been the most successful social media platform for marketing Prairie Sportsman and increased in likes by nearly 70 percent from January to August 2018. Snapchat and Instagram follow in popularity with Twitter being the least important in expanding Prairie Sportsman's audience.

Project Completed: 06/30/2019 **FINAL REPORT**

Standards-Based Dakota Indian Land Stewardship Education

Subd. 05f $197,000 TF

Darlene St. Clair
Dakota Wicohan
PO Box 2
Morton, MN 56270
Phone: (507) 697-6272
Email: dstclair@stcloudstate.edu
Web: http://www.dakotawicohan.com

Appropriation Language
$197,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Dakota Wicohan to enhance the capacity of approximately 1,250 students to be stewards of the land in Minnesota by learning about Dakota Indian values and environmental principles

through a standards-based experiential multimedia curriculum. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Dakota Wicohan connected 1,678 sixth-grade students from 14 urban, suburban, and rural schools to Mni Sota Makoce: The Dakota Homelands, a multi-media, standards-based curriculum that teaches students about Dakota values and environmental principles through a teacher training workshop and ten student lessons. A rigorous evaluation of 986 pre and post surveys revealed increases in student knowledge and understanding. Moreover, the results showed that statistically significant increases in learning happened across all racial/ethnic groups and throughout all districts. For instance, after completing the curriculum, students were 2.5 times more likely to understand that the Dakota concept of Mitakuye Owaysin, which teaches that humans are a relative of the land and of all things that exist on the land, in the air, and in the water. To gather qualitative data, the research teams also conducted over 40 talking circles in two urban and two rural schools. Analysis of this data noted students' growing relationship to the land. As one sixth grader said, "I feel like having learned about more about the Dakota and the culture that was here before settlers made me feel more connected to our land (in Minnesota)." Given the strength of these results, Dakota Wicohan has already embarked on further sharing this valuable curriculum with schools around the state. At least ten schools and districts are planning to attend curriculum training in the coming year, with the potential to reach more than 17,000 additional Minnesota learners. The project's success was made possible through strong partnerships cultivated and nurtured throughout the grant period. By preparing teachers to bring a new lens to teaching about the land and the Dakota people through Mni Sota Makoce, both the 1,678 students reached during the LCCMR grant period and the thousands of future students are poised to learn a new way of connecting to our relative, the land. To learn more, please visit the Mni Sota Makoce Curriculum page on the Dakota Wicohan website.

PROJECT RESULTS USE AND DISSEMINATION

Dakota Wicohan's curriculum project director Darlene St. Clair shared information about the Mni Sota Makoce: The Dakota Homelands curriculum with thousands of educators and potential partners throughout the grant project. Through outreach and additional web-based materials prepared in Summer 2019, thanks to help from the CREATE Scholars at the University of Minnesota-Twin Cities, we have already booked trainings for the 2019/2020 school year with multiple districts around the state, including: Anoka-Hennepin, St. Paul Public Schools, the Bell Museum, District 196 (Rosemount/Apple Valley/Eagan), District 742 (St Cloud), Onamia and other Central Minnesota schools. We will also be training all sixth-grade pre-service teachers at University of Minnesota-Morris as well as local public school teachers in Morris. We are also in conversation with Rochester for a regional training as well as Eastern Carver County. In conclusion, Dakota Wicohan is optimistic about the potential for the Mni Sota Makoce: The Dakota Homelands curriculum to reach more sixth-grade students every year so that one day all our citizens will gain the opportunity to reconnect with our land as a relative. We encourage you to check in to our website for further updates on the curriculum.

Project Completed: 06/30/2019 **FINAL REPORT**

Master Water Steward Program Expansion

Subd. 05h $116,000 TF

Leslie Yetka
Freshwater Society
2424 Territorial Rd Ste B
St. Paul, MN 55114
Phone: (651) 313-5800
Email: lyetka@freshwater.org
Web: http://www.freshwater@freshwater.org

Appropriation Language
$116,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Freshwater Society to train community volunteers as master water stewards who will work with neighborhoods to install water management projects that preserve and restore water quality. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Master Water Steward program quickly grew in size from its implementation in 2013 from 18 stewards to 340 at the beginning of 2019. A need also grew to expand the scope of the program as it reached the edges of the communities with urban water concerns (areas with curb and gutter). The program needed to address different issues and solutions for new areas of MN that had their own unique challenges. In addition, the program needed to be able to show the work of the many volunteers doing many different kinds of work, in a collaborative way.

The program needed a new "track" of the curriculum that taught rural stormwater runoff challenges and solutions for stewards that lived on the edge of or beyond the urban areas. Through this grant the program as able to implement that new track to the curriculum and offer it not just to new areas and people, but also offer it to certified stewards as additional learning.

The program also had a need for a collaborative approach to communicating the effectiveness of all of the Master Water Steward's work. The result of this grant is that we now have a functioning way of connecting stewards through a web application where they can report projects, volunteer time, and tell their stories. The work of the stewards is now available and accessible to stakeholders and program partners.

The overall success of this grant project was that it gave a well-established metro area program a solid new footing and improved educational and participatory structures to reach volunteers and program partners in all parts of Minnesota without losing the connection to the communities we have already built and continue to grow.

The number of Minnesotan's who will benefit from this work is unlimited. Each trained steward reaches hundreds of individuals through their work and keeps thousands of gallons of polluted stormwater from reaching our waterways each year. As we grow further, this will continue to be the case in each area we reach.

PROJECT RESULTS USE AND DISSEMINATION

Dissemination of these project outcomes has already begun and continues to be shared with every new partner organization and steward volunteer. We've created a Program Guide meant to help our partner organizations and volunteers work together and help them do their work. We have created a Capstone Guide that will help guide each project of a steward. We have a high-functioning web application to keep track of projects and volunteer time to help tell the collective story of the Master Water Steward

volunteers. And finally we have a curriculum that stewards who live inside of rural areas who can now take action for the health of their water and be included in the Master Water Steward community.

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 06 Aquatic and Terrestrial Invasive Species

Developing Membrane Filtration System to Treat Lake Superior Ballast Water

Research Project

Subd. 06b $151,000 TF

Santiago Romero-Vargas Castrillón
U of MN
Department of Civil, Environmental, and Geo- Engineering
500 Pillsbury Dr. SE
Minneapolis, MN 55455
Phone: (612) 301-1347
Email: sromerov@umn.edu
Web: http://www.cege.umn.edu/

Appropriation Language
$151,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a filtration system utilizing bioactive membrane technologies for use in treating Lake Superior ballast water to remove at least 90 percent of suspended pathogens, invasive species, and contaminants. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This project contributed novel membrane materials for water treatment, as well as new fundamental understanding of graphene oxide surface coatings that show potential in membranes for water purification. The materials explored in this work could find application in the treatment of surface water in Minnesota. An account of our work is provided in the Research Addendum that accompanies this workplan, as well as in our recent publication (Environ. Sci. Technol. Lett., 2018, 5 (1), pp 14–19). In summary, our work showed that graphene oxide coatings, covalently tethered to ultrafiltration membranes, inactivate bacteria and thus prevent membrane biofouling. Our work further showed that the nanoscale morphology of GO surface coatings affects membrane interfacial properties; we demonstrated that randomly oriented GO nanosheets are more desirable for membrane applications, since bacteria are less prone to adhere to disordered GO.

PROJECT RESULTS USE AND DISSEMINATION

Additional outcomes of this project were promotion of Minnesota's human capital through training of postdoctoral, graduate and undergraduate students (1 postdoc, 2 graduate and one undergraduate student were supported at various points of the project), a M. S. degree to be completed by one of the graduate students supported by the project (expected completion in early 2019), a conference presentation at the 2017 AEESP Research and Education Conference (presented by the postdoc supported by the project), a recent publication in Environmental Science & Technology Letters, a premier environmental engineering peer-reviewed journal, and a further manuscript currently under preparation.

In addition, the PM presented three oral presentations reporting the research funded by this project: a conference presentation at the ACS National Meeting in New Orleans on March 18th, 2018 ("Bacterial Adhesion on Surfaces Functionalized with Graphene Oxide: Insights from Single-Cell Force Spectroscopy"); and two invited seminars at the Department of Physics at Hamline University on April 6th, 2018 ("Computational and Experimental Studies of Aqueous Interfaces") and at the Department of Chemical Engineering at University College London on May 9th, 2018 ("Understanding Microbial Adhesion to Aqueous Interfaces using Single-Cell Force Spectroscopy").

Project Completed: 06/30/2019 **FINAL REPORT**

Bacterial Adhesion to Graphene Oxide (GO)

Biological Control of White Nose Syndrome in Bats - Phase II

Research Project

Subd. 06d $452,000 TF

Christine Salomon
U of MN
312 Church St SE, 4-130 Nils Hasselmo Hall
Minneapolis, MN 55455
Phone: (612) 626-3698
Email: csalomon@umn.edu
Web: http://www.cbs.umn.edu/contacts/christine-salomon

Appropriation Language
$452,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to continue research to identify, develop, and optimize biocontrol agents for white nose syndrome in bats by evaluating the biocontrol effectiveness of microbes collected at additional hibernacula throughout the state and conducting baseline characterization of the total bat microbiomes. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

White nose syndrome is a devastating disease of hibernating bats caused by the fungus, P. destructans (Pd). The primary goal of this project is to identify safe and effective bio-control treatments for WNS. We expanded our microbial strain collection and identified additional inhibitors of Pd, bringing our total of active strains to approximately 120. We identified the top five inhibitory strains, purified the active compounds, and determined their structures and activities. We identified approximately 15 structures new to science and 6 known compounds with antifungal activity. To determine the potential application of these active strains to substrates or bats, we developed a cell-based assay using bat skin cells derived from two bat species. By testing each compound against both the fungal pathogen and bat skin cells, we could calculate the relative potency and cytotoxicity. One of the most active and abundant compounds from an inhibitory fungus from the Soudan Iron Mine is completely nontoxic towards the cultured bat skin cells, which provides additional support for field testing with the producing strain.

Additional accomplishments include the sequencing of bacteria and fungi found throughout three distinct systems (iron mine, sandstone and calcium karst caves) from both culturable strains and mixed, non cultured microbial community samples. These taxonomic studies are significant because they allow

us to see patterns of microbial communities across diverse environments, including identifying taxa that are unique or common in different areas.

We also developed tools and techniques for monitoring P. destructans in caves for studies going forward. Mapping of P. destructans along two transects in the Soudan Mine and Mystery Cave using qPCR provides a clear picture of the density and occurrence of the pathogen. This information and testing will be used to target treatments in collaboration with the DNR and managers to ultimately protect the remaining bat populations.

PROJECT RESULTS USE AND DISSEMINATION

The primary dissemination of the results from this project has been through numerous seminars given at academic institutions, research symposia, and at professional science society meetings. Both lectures and posters have been presented at national conferences, and results have been shared with DNR staff through formal and informal communications. Two scientific manuscripts have been published on this work, and at least 5 more are in progress and should be published within the next 6 months. We have also participated in several outreach opportunities by having research tables at local bat week events, in collaboration with USFW staff.

The most immediate use of our results will be in collaboration with DNR staff and cave/mine park managers in locations affected by WNS. We are communicating our data about the pathogen locations to help inform any interventions and treatments, and to suggest specific areas for continued monitoring using our analytical approach.

Project Completed: 06/30/2019 **FINAL REPORT**

Complete Genome Sequence of Streptomyces Albus SM254

Resource Capture and Competitive Ability of Non-Pathogenic Pseudogymnoascus spp. and P. Destructans, the Cuse of White-Nose Syndrome in Bats

---

Elimination of Target Invasive Plant Species - Phase II

Subd. 06e $750,000 TF

Subd. 06e1 - $511,000 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

Web: http://www.mda.state.mn.us/en/plants/pestmanagement/weedcontrol/targetplants.aspx

Subd. 06e2 - $239,000 TF
Angela Gupta
U of MN
863 30th Avenue SE
Rochester, MN 55904
Phone: (507) 280-2869
Email: agupta@umn.edu

Appropriation Language
$750,000 the second year is from the trust fund. Of this amount, $511,000 is to the commissioner of agriculture and $239,000 is to the Board of Regents of the University of Minnesota to train volunteers and professionals to find, control, and monitor targeted newly emergent invasive plant species. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

ML2016 06e:

- *06e1: Elimination of Target Invasive Plant Species - Phase II* - $511,000
- *06e2: Elimination of Target Invasive Plant Species - Phase II* - $239,000

Subd. 06e1: Elimination of Target Invasive Plant Species - Phase II - $511,000 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
Web: http://www.mda.state.mn.us/en/plants/pestmanagement/weedcontrol/targetplants.aspx

OVERALL PROJECT OUTCOME AND RESULTS

The goal was to eliminate highly damaging target invasive plants before they became widespread by 1) training people to identify and report invasive plants, 2) survey, coordinate control and monitor target plants, 3) control target plants and 4) implement the invasive species management database system from Phase 1. Targeted plants that cause severe ecological harm include black swallow-wort, dalmatian toadflax, cutleaf and common teasels, Grecian foxglove, Japanese hops, brown and meadow knapweeds, Oriental bittersweet and Palmer amaranth.

University of Minnesota Extension led the education and outreach efforts outlined in the dissemination section. The drone team transitioned from research to survey work by testing several different types of drones, cameras, weather conditions and self-produced and commercial post-processing software. We determined that surveying for Oriental bittersweet is best done with sturdy quadcopter drones and a high quality camera on mild winter days after leaf drop but with snow on the ground so the red fruit is most visible. High quality, stitched-together and geo-coded maps can now be produced in post processing and inform accurate eradication efforts.

The Minnesota Department of Agriculture (MDA) and Conservation Corps Minnesota (CCM) led invasive plant management. MDA led survey, invasive plant report follow up, monitoring and coordinated control with landowners and partners. CCM led the control effort with 157 unique crew members working on this project.

This project enabled us to find, document and manage infestations before they spread. We also initiated a response to Palmer amaranth in conservation plantings that was continued by the project Palmer Amaranth Detection and Control. Mitigating these invasive plant threats protected Minnesota forests, grasslands and riparian areas.

PROJECT RESULTS USE AND DISSEMINATION

University of Minnesota Extension led the education and outreach funded specifically by this project. Reaching 1,108 people via 11 workshops, field tours and public and professional presentations. Developed two national award winning videos: Planning invasive species events: Tips for working with volunteers and Planning invasive species events: Working with a natural resources professional. Created 14 innovative educational materials including: 3D-printed models of Palmer amaranth, Japanese hops and Grecian foxglove; pull-up banners for Palmer amaranth and giant hogweed; and identification kits available at the public library for Palmer amaranth, wild parsnip and Oriental bittersweet. Produced two new educational handouts and printed and distributed about 10,875 educational materials. In addition, the University of Minnesota and Minnesota Department of Agriculture (MDA) team members won numerous national, regional and state awards for effort including this project, from across an impressively wide spectrum of content areas. There were 13 media pieces about project activities; 13 presentations or booths reaching 5,137 gardeners, tribal youth, Extension volunteers and others; and 30 presentations or posters at 14 different professional conferences representing a broad spectrum of expertise reaching almost 1,000 natural resource or invasive species professionals. Two professional, peer reviewed articles were published that reference this work. MDA organized and led 6 field tours, gave 43 presentations, provided project updates at 32 meetings, authored 14 articles, sent an annual report to stakeholders and trained Conservation Corps Minnesota crew members at multiple workshops each year.

Subd. 06e1 Completed: 06/30/2020 **FINAL REPORT**

Subd. 06e2: Elimination of Target Invasive Plant Species - Phase II - $239,000 TF

Angela Gupta
U of MN
863 30th Avenue SE
Rochester, MN 55904
Phone: (507) 280-2869
Email: agupta@umn.edu

OVERALL PROJECT OUTCOME AND RESULTS

Butterflies are in trouble in western Minnesota prairies. Ten species are of statewide conservation concern and two species are federally listed. Knowing where these species persist on the landscape is important to their conservation. Likewise, understanding the factors that affect population size is important to the conservation of existing populations. The skipper butterflies are difficult for untrained individuals to identify with certainty. The lack of qualified surveyors limits the ability of biologists and managers to search for skippers.

Seven of the 13 species were not found across all sites surveyed. All of these missing butterflies are skippers. We monitored populations of Dakota skipper and Pawnee skipper in response to prairie management. Conservation grazing, or perhaps the lack of fire, appears to be beneficial to persistence of Pawnee skipper. The results of Dakota skipper monitoring are less clear and will require additional years of monitoring. Dakota skippers at the reintroduction site appear highly localized to within a few hundred meters of the point of release. This is perhaps due to low dispersal ability, mortality, and/or lower detection ability with increasing radius from the release point. The MNDNR, MN Zoo, and USFWS partnered to successfully train at least 30 individuals to identify imperiled skippers, thus increasing the statewide capacity for monitoring greatly. All of these actions work to make more informed, science-based decisions about the conservation of rare butterflies for all Minnesotans to enjoy.

PROJECT RESULTS USE AND DISSEMINATION

During this project, the USFWS consulted project staff in drafting the recovery plans for both federally listed species, the Dakota skipper and the Poweshiek skipperling. Information gained from the surveys conducted through this project were essential in writing the recovery plans. These draft recovery plans were then disseminated for public comment and review.

The project manager in collaboration with the MN Zoo and USFWS developed species identification cards for the imperiled skipper species and their look-a-likes as part of the training sessions. These cards are specific to western Minnesota skippers and are an important tool in the continued survey and conservation of these rare skippers. We continue to receive complements and requests for these identification cards.

Subd. 06e2 Completed: 06/30/2020 **FINAL REPORT**

Dutch Elm Disease Resistance - Phase II

Research Project

Subd. 06f $200,000 TF

Robert Blanchette
U of MN
1991 Upper Buford Cir, 495 Borlaugh Hall
St. Paul, MN 55126
Phone: (612) 625-0202
Email: robertb@umn.edu
Web: http://forestpathology.cfans.umn.edu/default.htm

Appropriation Language
$200,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to continue to identify and evaluate native Minnesota elms that are resistant to Dutch elm disease and begin propagating disease-resistant specimens for field trial testing. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

After nearly a century since its introduction, Dutch elm disease (DED), caused by the fungal pathogen Ophiostoma novo-ulmi, remains a critical threat to elm populations in Minnesota. This iconic species has long been regarded as one of the most resilient and adaptive species for the upper Midwest, tolerating salt, pollution and many other stresses better than other trees. Elm also play a vital part in the ecology of Minnesota's forests, providing important food and habitat for wildlife, are excellent trees for wetlands and add to the biodiversity of a healthy forest. Combating this disease has been expensive and very difficult. Resistance to DED has been proven in American elm, however, it is poorly understood and a limited number of selections are available. Our objectives with this project were to survey and identify resistant elm trees in Minnesota, provide new insights on disease resistant mechanisms, and field test selections by inoculation studies. Our results showed different chemical and morphological characteristics that are in part responsible for resistant defense mechanisms. This information will lead to more rapid selection tools and development of increased resistance. We successfully identified, propagated, and screened 46 genotypes from which we hope to conduct continued long term trials with selections that perform well in field trials (based on 1 year inoculation data from a final field trial initiated 6/2019). In addition, because propagation of elm is variable and most often difficult, we developed enhanced propagation techniques that aid in and provide better efficiency to obtain the

numbers needed for screening trials. We are hopeful that this long term project aimed at developing and introducing resistant genotypes back into urban and forested areas will aid in overcoming the destructive impacts that this invasive disease has had on American elm.

PROJECT RESULTS USE AND DISSEMINATION

Presentation and demonstrations have been made at arborist and nursery meetings including the Minnesota Shade Tree Advisory Committee forum, the Minnesota Shade Tree Advisory Committee Annual Field Day, Minnesota Turf & Grounds Foundation and Minnesota Nursery and Landscape Association conventions, and a national workshop on American Elm Restoration in the United States. Documentation of results have been presented at scientific meetings and in general articles and scientific publications.

Project Completed: 06/30/2019 **FINAL REPORT**

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

Waste Heat Recovery with Efficient Thermoelectric Energy Generators

Research Project

Subd. 07b $400,000 TF

Uwe Kortshagen
U of MN
111 Church St SE
Minneapolis, MN 55455
Phone: (612) 625-4028
Email: kortshagen@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 develop thermoelectric energy generators using advanced, high-performance materials able to more efficiently capture waste heat and transform the heat into electricity. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Any thermal cycle, from combustion engines, to power plants, to refrigeration cycles produces waste heat that is not utilized but released into the environment. This project dealt with the fabrication of new thermoelectric materials, which are capable of converting part of that waste heat into electricity. The specific focus was on alloys of silicon (Si) and germanium (Ge), which are suitable for high temperature applications up to approximately 1,000 °C (approx. 1,830 °F). The focus of this project was on forming nanostructured materials that improve the thermoelectric performance by reducing the thermal conductivity of the material through scattering of heat conducting lattice vibrations at the abundant grain boundaries, without negatively affecting the electrical conductivity.

Initial work focused on forming bulk thermoelectric materials by sintering SiGe nanocrystals, particles with the size of only a few nanometers, into dense solids. However, this approach was found to be unsuccessful due to the brittleness of the material. Laser sintering of nanocrystals into thin film materials proved to be a much more successful approach, as it produced non-brittle thermoelectric thin

films, with performance comparable to the best SiGe materials previously reported in the literature. Furthermore, laser sintering was found to be a fast, high-throughput method which has the potential to be applicable in industrial processes.

The porosity of laser-sintered films was identified as a potential weakness. To overcome this issue, the team developed a new approach to from nonporous nanocrystalline thin films by first plasma depositing amorphous (non-crystalline) SiGe materials, and then using thermal annealing to transform these into nanocrystalline materials. This approach was found to yield virtually fully dense thermoelectric materials with good performance characteristics and the promise of low-cost production.

The work performed under this project has made important contributions to the scientific community, documented in several scientific papers, and may lead to the production of new thermoelectric materials that convert waste heat into electricity. This has the potential to improve the efficiency of thermal cycles and reduce the energy lost in waste heat, which will ultimately benefit Minnesota citizens and all of humanity.

PROJECT RESULTS USE AND DISSEMINATION

By the time of the project final report, results of this research have been disseminated in seven scientific journal publications and through five presentations at international conferences.

Project Completed: 06/30/2019 **FINAL REPORT**

Hydrogen Fuel from Wind-Produced Renewable Ammonia

Research Project

Subd. 07c $250,000 TF

William Northrop
U of MN
111 Church St SE
Minneapolis, MN 55455
Phone: (612) 625-6854
Email: wnorthro@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 technical solution for converting wind-produced ammonia to hydrogen through catalytic decomposition, for use in reducing emissions from diesel engines and powering fuel cell vehicles. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

Project due to be completed: 06/30/2019 **Work Plan**

Utilization of Dairy Farm Wastewater for Sustainable Production

Subd. 07d $475,000 TF

Bradley Heins
U of MN

46352 State Hwy 329
Morris, MN 56267
Phone: (320) 589-1711
Email: hein0106@umn.edu
Web: http://wcroc.cfans.umn.edu/research-programs/dairy

Appropriation Language
$475,000 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 in Morris to develop and evaluate an integrated system that recycles and uses nutrients in dairy wastewater from feedlots and milk processing, thereby reducing nutrients from agricultural runoff, and to provide outreach on adoption of new technologies. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The work was a collaboration between the West Central Research and Outreach Center in Morris and in the Department of Bioproducts and Biosystems Engineering and Food Science and Nutrition at the University of Minnesota. The goal of our project was to use dairy cattle wastewater to produce green energy, foods, and feed for livestock. The project utilized algae cultivation to remove nutrients from dairy wastewater and produce algae biomass for dairy calf feed, as well as hydroponic vegetables. Chlorella species of algae was the most predominant algae studies in the project, and the fatty acid profile of Chlorella indicated it would be superior of livestock feed and energy. Our project found that algae can successfully remove nitrogen, phosphorous, and dissolved solids in dairy wastewater, thus improving the environmental effects of wastewater from livestock farms. Results also suggest that feeding algae grown from dairy wastewater provided acceptable nutritional requirements for dairy cattle and mice. No adverse growth of calves or feed intake was observed when adding algae to dairy calf rations. This project suggests that algae can clean Minnesota waterways through reduced nitrogen and phosphorous from agricultural runoff.

PROJECT RESULTS USE AND DISSEMINATION

We have provided tours of the algae biomass system at the WCROC to legislators, farmers, and industry representatives. We have also hosted dairy field days and the Midwest Farm Energy Conference at the WCROC that have shown the results and bioreactors to the public as well. Over 2,000 people have viewed the system and have responded with favorable interest in the system. Our graduate student on the project presented an abstract at the Algal Biomass Conference in Denver, CO on biomass production for livestock. So far, 18 peer reviewed papers have been published with more to follow. The website will be updated with the final results of the project and infographics for promotion of the project. An abstract on calf feeding with be presented at the American Dairy Science Association meeting in 2020. This applied algae livestock feeding component is the Master's thesis of Siane Luzzi in the Department of Bioproducts and Biosystems Engineering at the University of Minnesota and she will defend her thesis in 2019.

Project Completed: 06/30/2019 **FINAL REPORT**

Solar Energy Utilization for Minnesota Swine Farms - Phase II

Subd. 07e $475,000 TF

Lee Johnston
U of MN - West Central Research and Outreach Center
46352 State Hwy 329
Morris, MN 56267
Phone: (320) 589-1711
Email: johnstlj@morris.umn.edu
Web: http://wcroc.cfans.umn.edu

Appropriation Language
$475,000 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 in Morris to continue to develop and evaluate the utilization of solar photovoltaic systems at swine facilities to improve energy and economic performance, reduce fossil fuel usage and emissions, and optimize water usage. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

American pork producers are trying to improve the environmental footprint of their production systems by reducing their reliance on fossil fuels. Keeping sows and pigs in their ideal temperature range during hot seasons is one way to improve animal performance and the carbon footprint of their production system. Use of solar-generated electricity is another approach for pig farmers to reduce their reliance on fossil fuels. We designed and installed a solar-powered system to cool heat-stressed sows during the farrowing and lactation periods. After installation and commissioning, we studied 84 sows and litters over two summer seasons in three contemporary groups of sows. The 20 kW solar array consistently provided enough electricity to operate the sow cooling system installed in a confinement farrowing barn. The sow cooling system studied in this project was able to significantly reduce heat stress and improve welfare of farrowing and lactating sows. Unfortunately, the reduced heat stress of sows did not support improvements in litter size at weaning or growth rate of suckling pigs. A basic economic analysis of the 20 kW solar PV system installed for this project suggested the system would breakeven after 60 years on a straight cash basis (revenues minus expenses). When tax incentives are added and fully utilized, the breakeven point is between 8 and 12 years but can depend on the utility provider in the area. A Life Cycle Assessment (LCA) of the carbon and energy footprints of the sow cooling system was completed. Because there was no increased output (number or weight of weaned pigs) as a result of the cooling system, neither the carbon footprint nor the energy footprint of the farrowing operation were improved by the cooling system. However, using electricity generated by the solar PV system did substantially reduce the carbon footprint and also significantly reduced the consumption of energy derived from fossil fuels for the swine farrowing operation. Solar-generated electricity can play an important part in reducing carbon emissions from Minnesota pork production.

PROJECT RESULTS USE AND DISSEMINATION

Information related to this project has been disseminated to many different audiences in a variety of formats. The target audiences for these publications include: pig farmers, engineers and builders of swine production barns, swine industry consultants, and consumers. Publications related to this project include: a video about the project (Cooling Sows and Heating Piglets with Solar Energy) and two factsheets (WCROC Farrowing Barn Heating and Cooling System and Lactating Sow Performance with Solar-Powered Cooling). Multiple conference presentations and posters were made for industry and professional audiences, and many articles were printed in newsletters and popular press, including the West Central Research and Outreach Center Newsletter, Land Magazine, Morris Star Tribune Ag Supplement, The Farmer Magazine, and Minnesota Pork Congress Magazine. Any of these publications are available upon request from the project manager. More publications are anticipated in the future.

Project Completed: 06/30/2019 **FINAL REPORT**

Life Cycle Assessment of Cooling Sows Using Solar Electricity
Effects of a Solar Cooling System on Sow Performance

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

Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity

Research Project

Subd. 08b $556,000 TF

Lauren Sullivan
U of MN
1987 Upper Buford Cir, 100 Ecology Bldg
St. Paul, MN 55108
Phone: (612) 301-1056
Email: lsulliva@umn.edu

Appropriation Language
$556,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to determine habitat connectivity between prairie fragments by measuring plant movement by dispersal of pollen and seeds to improve prairie restoration implementation. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

Project due to be completed: 06/30/2019 **Work Plan**

Establishment of Permanent Habitat Strips Within Row Crops

Subd. 08c $179,000 TF

Shawn Schottler
Science Museum of Minnesota
16910 152nd St N
Marine on St. Croix, MN 55047
Phone: (651) 433-5953 x18
Email: schottler@smm.org

Appropriation Language
$179,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix Watershed Research Station to research the viability of establishing prairie forbs and alfalfa as permanent cover strips in the bare soil between selected rows of corn and soybeans as potential pollinator, monarch, and gamebird habitat. Monitoring of the native plant strips must evaluate the effects of pesticides from adjacent crops on pollinators, including determining whether there is a reduction of pollinators that results in reduced setting of seeds on the native plants. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This project successfully demonstrated three objectives: 1) that perennial vegetation can be established and maintained between rows of corn/soy within a field—without taking land out of production; 2) that the perennial vegetation in the inter-row plantings provides habitat value, and 3) that the plantings can be done in a manner that induces a minimal yield loss to the adjacent corn/soy rows. While establishment of many prairie species in the inter-row strips failed, several did not and are thriving after three years. We have demonstrated that species such as golden alexanders, bottlebrush grass and milkweeds can be established and maintained in a conventional corn/soy rotation. These strips of perennial forbs and grasses were documented to have provided habitat to pollinators and appear to be very good reproduction habitat for monarch butterflies. Perennial strips did induce a 5 to 20 bushel per acre yield loss, but since only 1 out of 24 inter-row strips were planted with perennials, we estimate that the total cost in lost yield for the whole field (80 acres) due the perennial strips is less than $200. Going forward, we think it is possible to plant and maintain just the outside row of a field with a mix of golden alexander, milkweeds, and woodland brome. This mix would provide some early season pollinator habitat and a significant amount of summer Monarch reproduction habitat. And, since only the outside row of a field would be impacted, the total annual cost in lost yield and maintenance of the strip should be under 40 dollars per 80 acres. If implemented on a widespread scale, this could offer a very cost-effective way to provide significant benefit to Monarch populations.

PROJECT RESULTS USE AND DISSEMINATION

Results of this project were presented at two farm-day tours as part of the semi-annual Agroecology summit hosted at Willow Lake farm. Combined, there were over 150 participants in the two Agroecology summits with nearly all of these participants given a first-hand tour of the inter-row perennial vegetation strips implemented during this project. Participants included many local farmers testing cover cropping techniques to improve soil health, as well as agency and advocacy professionals and practitioners working to implement perennial cover as habitat or new cropping systems. In addition to the on-site demonstration of the strips, the field days featured presentations and panel discussion by U of MN faculty, Science Museum scientists, MN-DNR biologists, BWSR planners, environmental advocacy groups and local farmers. Both Agroecology summits presented new concepts/methods about existing and emerging cropping systems that incorporate perennial vegetation (including results from the perennial inter-row system of this project); and policies and technology that could be used to stimulate perennial cropping systems. In-depth presentations were given on why perennial systems are needed, how they are critical to improving water quality and wildlife habitat, what future perennial systems could look like, and how manipulating food and energy markets could be a cost-effective method to getting perennial crops/vegetation adopted. The strips project, with its embedded objectives of habitat and water quality, while maintaining ag-profitability, provided a good backdrop to start the conversation about how we are going to modify cropping systems to more cost-effectively meet our natural resources goals.

Project Completed: 06/30/2019 **FINAL REPORT**

Controlling Reed Canary Grass to Regenerate Floodplain Forest

Research Project

Subd. 08e $218,000 TF

Luis Ramirez
Audubon Minnesota

1 W Water St #200
St. Paul, MN 55107
Phone: (651) 739-9332
Email: luis.ramirez@audubon.org

Appropriation Language
$218,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Minnesota state office of the National Audubon Society to determine the most effective regeneration methods for restoration of floodplain forests in southeast Minnesota impacted by invasive reed canary grass. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

As a result of this work, the research team has identified that the most important considerations for long-term control of Reed Canarygrass include:

- Treat reed canarygrass until it is controlled (this will take 2+ years)
- Controlling reed canarygrass before planting other species is key for survival
- Diversify your site and plant as many species as practical
- Floods and site conditions may delay treatments and tree planting

A decision making tool was developed to guide efforts to restore reed canarygrass to a native floodplain forest community. It includes guidance for treating the grass and restoring native species in both open field and forest gap settings. These recommendations are based on scientific field studies that tested a variety of approaches. Much of the research that forms the basis of these recommendations was conducted between July 2017-June 2019 at four sites in floodplain forest along tributaries of the Mississippi river between Red Wing, MN and the Iowa border (see case study from one site by Beebe 2019). These years were generally warm and wet experiencing longer duration and more frequent inundation than average conditions. Fall 2018 was warm and plants senesced late.

PROJECT RESULTS USE AND DISSEMINATION

The materials produced as part of the decision making tool to control Reed Canarygrass will be available electronically at the Audubon Minnesota webpage. Subsequently, computer files will be made available to state, federal and private land management agencies.

Project Completed: 06/30/2019 **FINAL REPORT**

Upland, Wetland, and Shoreline Restoration in Greater Metropolitan Area

Subd. 08g $509,000 TF

Wiley Buck
Great River Greening
35 Water St W, Ste 201
St. Paul, MN 55107
Phone: (651) 665-9500
Email: wbuck@greatrivergreening.org
Web: http://www.greatrivergreening.org

Appropriation Language
$509,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Great River Greening to restore approximately 150 acres of forest, prairie, woodland, and wetland and 0.15 miles of shoreline throughout the greater Twin Cities metropolitan area, using volunteers, and to conduct restoration evaluation on previously restored parcels. A list of proposed restorations and evaluations must be provided as part of the required work plan. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Over the course of the appropriation,
we:

- Restored/enhanced 342 acres of high quality natural areas. This is more than double our original goal of 150 acres.
- Restored/enhanced 0.29 miles of shoreline, which is 116% of our original goal.
- Engaged 839 volunteers – 129% of our original goal of 650 - who participated in deeply engaging, impactful outdoor activities so they and the community better understand, support, and enjoy the ecological restoration/enhancement process.
- Continued to advance the practice of restoration/enhancement with developing feasible new approaches at a challenging site, and collected valuable information with a sample of restoration evaluations.
- Leveraged $176,000 in match, including cash and in-kind, from a variety of sources. This is 94% of our goal, comparable to our proportional spend of 93% of the allocation.

The successful use of this appropriation underscores the continued importance of our ecological restoration and enhancement work, which is rooted in partnerships, community engagement, and sound practice.

PROJECT RESULTS USE AND DISSEMINATION

Over 830 volunteers received active education including results of project, techniques, and answers to specific questions during participation in volunteer restoration/enhancement events. Emails about these volunteer events were sent over 15 times to our 8500 general subscribers, and over 30 times to our 350 Volunteer Supervisor subscribers who also received a packet of information when they led a small group of general volunteers. All volunteers received follow-up thank you emails recapping the project. Events were also posted several times on Twitter, with 600 followers, and at least 6 Facebook posts with 1400-1500 followers. Two website posts with 1500 views per month, featured volunteer events. Over 1300 hard copy fliers, and 4800 hard copy/digital mix of fliers featuring events were distributed at over 20 outreach events. One site was featured on a Kare11 news article.

To advance the practice of restoration and enhancement, GRG partnered with a subcontractor for their powerpoint presentation ‘Hay Now!’ at the 11th Annual Scientific Meeting ‘Cultivating Innovative Restoration Connections in the Midwest’ of the Society for Ecological Restoration Midwest Great Lakes Chapter April 12-14, 2019 at Central College in Pella, Iowa. The meeting was attended by over 200 restoration ecologists. This presentation featured two case studies of conservation haying at Pilot Knob Hill (ML2016) and South Washington Conservation Corridor (ML2015).

Project Completed: 06/30/2019 **FINAL REPORT**

Bluffland Restoration and Monitoring in Winona

Subd. 08h $99,000 TF

Neal Mundahl
Winona State University
175 Mark St W
Winona, MN 55987
Phone: (507) 457-5695
Email: nmundahl@winona.edu
Web: https://www.winona.edu/outdoored/arboretum.asp

Appropriation Language
$99,000 the second year is from the trust fund to the Board of Trustees of the Minnesota State Colleges and Universities system for Winona State University to inventory, restore, and monitor the 40-acre Garvin Heights Natural Area in Winona and provide related public outreach and education. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

A 40-acre bluffland park in Winona, MN, containing rare dry bluff prairies and bur oak savannahs adjacent to a heavily visited (40,000+ visitors annually) overlook, became overrun with invasive buckthorn and honeysuckle. This project planned to restore the native plant community by 1) surveying the existing plant community, 2) removing invasive plants, 3) planting and seeding native plants, 4) conducting workshops on invasive plant management for the public, and 5) surveying the recovering plant community. Pre-restoration plant surveys indicated low numbers of native plant species. Cutting, treating, and burning by the MN Conservation Corps and browsing by goats (five separate periods over 3 years) were used to help reduce and manage the invasive plants. Native plants were planted and seeded to restore the natural community. During restoration, two public workshops were held to educate area citizens on methods for managing invasive plants on their own lands and restoring native plant communities. Recent plant surveys have documented the presence of 181 species at the site to date, with 127 of those not present before restoration. A large, reproducing population (>600 plants) of a state threatened species, Great Indian Plantain, has developed after buckthorn removal from one area of a savannah. A Winona State University (WSU) graduate student completed a thesis focused on the restoration effort and the workshops, developing a basic management plan for the site moving forward. Restoration efforts will continue, with ongoing management of buckthorn emerging from the seedbank and the germination and spread of newly planted native species. WSU has funded a new graduate assistantship (tuition plus stipend) to continue the restoration and monitoring work at the site. This project, along with new educational signage for the site, will demonstrate to the public the methods and benefits of managing invasive plants on natural habitats.

PROJECT RESULTS USE AND DISSEMINATION

1. Throughout the project period, various information about the project was posted on the project web site maintained by Winona State University (https://www.winona.edu/outdoored/garvin.asp), on a project-specific Facebook page

(https://www.facebook.com/Garvin-Heights-Natural-Area-Blufflands-Restoration-Project-357534101286304/), and on the Winona State Biology Department Facebook page (https://www.facebook.com/biologyWSU/). The community was informed of upcoming workshop opportunities via hard-copy postings within the community, targeted mailing, Facebook postings, group email lists, newspaper notifications, and a radio broadcast. Workshops, community presentations, on-site signage, and presentations at regional science meetings further served to present the project and its findings to the public.

2. Prior to site restoration, plant surveys on-site were used to produce a list of species present. In addition, a list species in the WSU herbarium collected from Garvin Heights was generated. (spreadsheets included via email)
3. Presentations about the project and its results were given by the PI (Winona Master Gardeners, Mississippi River Research Consortium) and by several undergraduate students (WSU Ramaley Undergraduate Research Celebration).
4. Graduate student Ryan Walsh recently completed his thesis (Walsh, R. 2019. Garvin Heights Restoration Project. Professional Science Masters Thesis, Winona State University, Winona, MN. 56 p.) that focused on the Garvin Heights project in general, the first workshop, and the effects of goat browsing on buckthorn. Included in his thesis are a series of recommendations for future management at the project site that will form the basis for a future management plan. In the near future, we plan to develop a manuscript from his thesis, on the effects of goat browsing, for submission to a peer-reviewed scientific journal. (thesis included via email)
5. Graduate student Tamberlain Jacobs is creating an up-to-date plant inventory list for the project site. She also is developing a bloom calendar for the site, which will allow visitors to determine what plants may be in bloom at various times of the year. (spreadsheets included via email)

Project Completed: 06/30/2019 **FINAL REPORT**

Master Thesis: Garvin Heights Restoration Project

Champlin Mill Pond Shoreland Restoration

Subd. 08i $2,000,000 TF

Todd Tuominen
City of Champlin
11955 Champlin Dr
Champlin, MN 55316
Phone: (763) 923-7120
Email: ttuominen@ci.champlin.mn.us
Web: http://www.ci.champlin.mn.us

Appropriation Language
$2,000,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the city of Champlin to restore the Champlin Mill Pond shoreline and adjacent habitat. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Mill Pond is a reservoir lake within the City of Champlin that was created in 1867 with the construction of the first Mill Pond Dam on the Elm Creek, at the outfall to the Mississippi River. Since that time, the Mill Pond has become an important water feature for fishing and recreational activity in the region. Over the years, the Elm Creek and Mill Pond have become impaired due to poor agricultural practices and upstream erosion. The Mill Pond impairments are for Total Suspended Solids, phosphorous, bacteria and low dissolved oxygen. In 2012, the City completed the first stream restoration project upstream of the Mill Pond and completed the reconstructed Elm Creek Dam and shoreland restoration at the Mississippi River outfall in 2016.

In 2016-2017, the City established partnerships with the LCCMR, MN legislature, and Elm Creek Watershed to restore the Mill Pond and improve water access. A Technical Advisory Panel was formed to guide the design and develop project goals for Habitat Restoration; Water Quality Improvements; Public Education; Public Access and Recreation.

Phase I started in December 2017, and included the removal of phosphorus laden sediments, installation of the redesigned deep-water and shallow water habitat and in-lake structures. The project restored approximately 42 acres of shoreland area and aquatic habitat. The project restored native upland, riparian, and aquatic zones. The project outcomes include a reduction in erosion and improves water quality. The restored habitat will help maintain and enhance sensitive species like the Blanding's Turtle and sustain game-fish populations. The improved riparian and upland habitats help support migratory and resident wildlife populations.

The lake restoration was completed in June 2019 and the City held the first Mill Pond Citizen Science Event at the Mill Pond. The event provided hands-on interactive activities and educational experiences on fishery research, migratory birds and preservation of native plant communities. The project established an area of study for environmental science classes for area schools, which are expected to educate hundreds of students each year. Also, the completion Phase II Mill Pond Trail Access project has improved the water access and recreational experiences for area residents.

PROJECT RESULTS USE AND DISSEMINATION

Project status has been posted on Facebook and on the Champlin website. Public Hearing and related articles on regarding the project were published in the Champlin Dayton Press. Additional articles in the Champlin Chronical have been published and distributed to area residents. The City working with local Cable Station Quad City Television (QCTV) had production of "Champlin Matters" focusing on the Citizen Science and the development of the Mill Pond In-lake Habitat and Fishery. Also, Champlin Live and Local production focused on the Mill Pond.

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 09 Land Acquisition, Habitat and Recreation

Scientific and Natural Area Acquisition and Restoration

Subd. 09a $1,386,000 TF

Ann Pierce
MN DNR
500 Lafayette Rd, Box 25
St. Paul, MN 55155-4025
Phone: (651) 259-5119

Email: ann.pierce@state.mn.us
Web: https://www.dnr.state.mn.us/snas/index.html

Appropriation Language
$1,386,000 the second year is from the trust fund to the commissioner of natural resources to restore and improve approximately 750 acres of scientific and natural areas. A list of proposed restorations must be provided as part of the required work plan. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Through this appropriation, habitat restoration and enhancement activities took place across the state on Scientific and Natural Areas (SNAs) to sustain the unique plant communities and the endangered, threatened, and rare species housed within these SNAs. Activities included 50.2 acres of habitat restoration (see restoration evaluations included with final report), 539 acres of invasive species control, 460 acres of woody control, 523 acres of prescribed burning, site development work at 22 SNAs, development of 7 interpretive signs, the completion of 12 Adaptive management Plans, ecological monitoring at 54 SNAs and partnership project activities at 6 SNAs. Partnership Projects coordinated through this appropriation led to multiple invasive control, woody control, prescribed burning and prairie restoration activities being completed.

Knowledge gained through ecological monitoring efforts will enable managers to improve management of SNA's unique plant communities and the Species in Greatest Conservation Need, state special concern and state/federally threatened and endangered species that call these habitats home. As best management practices are evaluated and improved through these efforts, SNA will be able to disseminate this knowledge to other landowners and land managers.

PROJECT RESULTS USE AND DISSEMINATION

Seven new interpretive signs were developed and installed at SNAs to communicate the significance of protecting these unique habitats and the role that restoration and enhancement play in sustaining or improving habitat quality. Several management activities completed through this appropriation have been highlighted on the SNA Facebook page and in the SNA program e-newsletter.

Project Completed: 06/30/2019 **FINAL REPORT**

Conservation Easements in the Avon Hills - Phase III

Subd. 09c $1,300,000 TF

John Geissler
Saint Johns Arboretum and University
PO Box 3000
Collegeville, MN 56321
Phone: (320) 363-3126
Email: jgeissler001@csbsju.edu
Web: http://www.csbsju.edu/arboretum/avonhills

Appropriation Language
$1,300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Saint John's University in cooperation with Minnesota Land Trust to secure permanent conservation easements on approximately 500 acres of high-quality habitat in Stearns County, prepare

conservation management plans, and provide public outreach. A list of proposed easement acquisitions must be provided as part of the required work plan. An entity that acquires a conservation easement with appropriations from the trust fund must have a long-term stewardship plan for the easement and a fund established for monitoring and enforcing the agreement. Funding for the long-term monitoring and enforcement fund must come from nonstate sources for easements acquired with this appropriation. The state may enforce requirements in the conservation easements on land acquired with this appropriation and the conservation easement document must state this authority and explicitly include requirements for water quality and quantity protection. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Conservation easements to permanently protect private land from development are the main goal of this project located in the Avon Hills 10 miles west of St. Cloud, MN. The project permanently protected 477 acres of forests, grasslands, wetlands, and almost 3 miles of undeveloped shoreline in the Avon Hills through the acquisition of two conservation easements. These two conservation easements continue to demonstrate the effectiveness of a reverse bidding system termed the MN Multi-faceted Approach for Prioritizing Land Easements (MMAPLE) to rank submitted easement locations. MMAPLE ranks proposed easements by comparing the land's inherent ecological features to the cost per acre for the easement, thereby focusing on the best value. Land which has many inherent ecological values receives a higher score. Conversely, landowners who bid a higher price per acre for the easement receive a lower score.

Using this competitive bidding process, MMAPLE again proved its ability to efficiently leverage the grant funding. For example, the Serenity easement acquisition was purchased for $201,100 below its full market value. Appraised value of the two purchased easements in this phase was $1,191,000, with the grant providing $989,900 towards acquisition; donated value of the bargain sale, in conjunction with landowner contributions to the Land Trust's stewardship fund ($40,000) amounted to $241,100 of total leveraged funds (almost $100,000 more than estimates in the original proposal).

The grant also provided funding to support outreach and education to increase landowner awareness of easements and land protection as well as overall conservation. Examples of the varied educational programming offered reaching over 2000 participants included the Living in the Avon Hills Conference, MN Master Naturalist Volunteer trainings, Collegeville Colors, monthly Landowner Learning Series, and an Avon Hills Master Woodland Owner Training.

PROJECT RESULTS USE AND DISSEMINATION

The Land Trust shared news of the easement acquisitions on both the Avon Hills (Serenity) and (Redhead) parcels on its website and Facebook page. Multipage newsletters and flyers featuring the easements and educational programming were mailed to every landowner with over 40 acres in the Avon Hills several times throughout the project. The MMAPLE process used in this project is being advocated for use in other grants and for other funders such as the Lessard-Sams Outdoor Heritage Council and will be presented as a topic at the national conference of the Land Trust Alliance in Raliegh, NC in October, 2019.

Project Completed: 06/30/2019 **FINAL REPORT**

Lincoln Pipestone Rural Water System Acquisition for Wellhead Protection

Subd. 09d $1,500,000 TF

Jason Overby
Lincoln Pipestone Rural Water System
415 Benton E
Lake Benton, MN 56149
Phone: (507) 368-4248
Email: lprw@itctel.com
Web: http://www.lprw.com

Appropriation Language
$1,500,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Lincoln Pipestone Rural Water to acquire and restore lands designated under an approved wellhead protection plan. Lands acquired with this appropriation must be from willing sellers and be identified by the Department of Health as targeted vulnerable lands for wellhead protection. Lands must be restored to permanent vegetative cover, but may be used for recreation and renewable energy if adequate protection of the drinking water aquifer is provided. A list of proposed acquisitions must be provided as part of the required work plan. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. Income derived from the lands acquired with funds appropriated under this paragraph is exempt from Minnesota Statutes, section 116P.10, if used for additional wellhead protection as provided under this paragraph until adequate wellhead protection has been achieved, as determined by the commissioner of health. Any income earned after that must be returned to the environment and natural resources trust fund. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Lincoln-Pipestone Rural Water (LPRW) System, a regional public drinking water system located in 10 counties in southwestern Minnesota, faces a number of water quality issues within its wellhead areas. These shallow, highly vulnerable aquifers are situated within intense agricultural areas; having row copping as the primary land use. Excess nutrients, particularly nitrates, and chemical applications can move quickly through the porous soil profiles contaminating drinking water supplies. Conservation practices to guard against agricultural contamination can help but most have severe limitations for drinking water protection. Thus, Fee Title ownership and permanent control over restoration and maintenance by the public water supplier is needed to best protect drinking water supplies.

LPRW applied for and received $1,500,000 in funding from the Environmental Natural Resource Trust Fund to identify and purchase parcels in Fee Title within three highly vulnerable wellhead areas. Parcels were ranked according to proximity to drinking water supply wells and in correlation to hydrogeological information documented within LPRW’s Wellhead Protection Plan. Individual landowners were engaged, according to their parcel ranking, to determine willingness to participate in a land transfer/purchase. Acquisition(s) would be through negotiated, voluntary or by direct purchases. Grant requirements stipulated that any land acquisition could not exceed the appraised value for that property. Any parcels acquired were to be restored to native grassland adhering to Minnesota Board of Water and Soil Resources Native Vegetation guidelines.

Several properties were investigated; with little success. Setbacks included lack of interest, absentee ownership or values exceeding project budget. A property containing approximately 200 acres located in the Verdi Wellfield, Lincoln County, became available through public auction. LPRW obtained this critical property through winning bid, having bid under appraised value. This parcel was taken out of agricultural production and restored to permanent grassland; providing long-term protection for highly vulnerable drinking water supplies.

PROJECT RESULTS USE AND DISSEMINATION

The Lincoln-Pipestone Rural Water (LPRW) System Land Acquisition for Wellhead Protection Project focused on targeting acquisition of land parcels residing within three (3) highly vulnerable wellhead protection areas. No material resources, tools or documents were generated for intended public use as a result of this project. However, information about this project has been published through various platforms including LPRW Annual Newsletters, LPRW website and presentations given to community service events. Three Annual Newsletters (2016, 2017 and 2018) were produced by LPRW and reference this project.

Project Completed: 06/30/2019 **FINAL REPORT**

Mesabi Trail Segment from Highway 135 to Town of Embarrass

Subd. 09e $1,200,000 TF

Robert Manzoline
St. Louis & Lake Counties Regional Railroad Authority
111 Station Rd
Eveleth, MN 55734
Phone: (218) 744-2653
Email: bmanzoline@rrauth.com

Appropriation Language
$1,200,000 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 engineering and construction of segments of the Mesabi Trail, totaling approximately six miles between Highway 135 and the town of Embarrass. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The project as originally described in the ML 2016 Work Plan changed significantly. The wetlands encountered due to the fact that Lane 51 had settled into the Wildlife Management Area required construction of a 0.9 miles floating bridge. The Historic Embarrass River Bridge required rehabilitation. These improvements made it necessary to phase the project and apply for additional funding. The route from Soini Palo Tia intersection to Embarrass changed and the north terminus of this trail segment in Embarrass also changed. The total length of the revised Hwy 135 to Embarrass segment is 5.23 miles.

Phase 1 of this trail segment starts at the intersection of Highway 135 and the trail from the Giants Ridge Ski and Golf area and runs 3.33 miles east and north to the intersection of the Soini and Palo Tia Roads. The 3.33 miles includes the 0.9 miles floating bridge.

Phase 2 of this segment starts at the terminus of Phase 1, intersection of Soini and Palo Tia Roads, follows Palo Tia Rd. north to CR 21, and then east along on CR 21 and terminates at Sauna Rd. (CR 627) for a length of 1.9 miles. This will be the beginning of the next proposed segment of the trial from Sauna Road to Wahlsten Road (CR 26) which will be 9 miles in length. The construction of Phase 2 and the Sauna Road to Wahlsten Road CR 26 segment will be completed by future grants.

Construction of the segment from Darwin Meyers WMA to County Road 21 (Phase 2) is now being considered for 2019 LCCMR funding as seen within the approved draft WP dated November 29, 2018. In addition, construction of the proposed Embarrass to Kugler, trail segment also being considered for

2019 LCCMR funding as seen within the approved draft WP dated November 29, 2018. The bituminous paving, aggregate shouldering, erosion control, seeding, signage, floating bridge ramps, pavement handicap truncated domes, culvert extension for floating bridge construction, silt fence removal and ditch check construction were completed in August and September. The project is complete and will start the one year warranty period when the final project documents have been filed.

This segment of the trail offers a variety of geography and trail construction features. As you travel the trail you experience glacial boulders and ledge rock, to the old Lane 51 alignment, to the massive Darwin Meyer's Wildlife Management area on the 0.9 miles long floating bridge, and back to Lane 51 over the historic Embarrass River bridge. The WMA also has evidence of turn of the century farmsteads that were grubbed out of the wilderness by the early settlers.

PROJECT RESULTS USE AND DISSEMINATION

There are 180,000 trail users per year and 700 riders registered for the yearly "Mesabi Trail Tour." A group from the University of MN Duluth will be visiting the bridge in August 2019. We have also received calls from the Gitchi Gammi State Trail and the Lake Vermillion Trail requesting information on the bridge for use on their projects.

Progress of this trail development has been posted on multiple websites (noted below) and has drawn attention particularly for the design/construction of the floating bridge including: Club Mesabi (10,000 maps & web site), Iron Range Tourism (30,000 brochures & web site), MN Office of Tourism, Ampers Radio, Parks & Trails, Home & Away, other private magazines, Named by the Star Tribune as "Best of Minnesota" in year 2013, Named by Bicycle Magazine as" top 10 in the country", and Mesabitrail.com.

Project Completed: 06/30/2019 **FINAL REPORT**

Tower Historic Harbor Trail Connections

Subd. 09f $679,000 TF

Nancy Larson
City of Tower
PO Box 576
Tower, MN 55790
Phone: (218) 753-4070
Email: communitycoaching@yahoo.com
Web: http://www.cityoftower.com

Appropriation Language
$679,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the city of Tower to construct recreational trails along the harbor in Tower and to connect to the Mesabi Trail. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Tower Historic Harbor Trail Connection in Tower, Minnesota, located in the East Two River and West Two River waterway to Lake Vermilion, is completed. A new pedestrian/biking trail was constructed around Tower's redeveloped harbor and routed under the highway bridge to enhance and connect to existing recreational and natural resource assets.

On the north side of the harbor trail 150 feet of trail length was identified to have wetland, waterway, and open water vegetation impacts. Helical piers were installed to support this area from future settlement and a floating walkway was installed at higher cost to avoid natural resource impacts. Soil conditions created challenges for the project. Less than ideal soils in the trail area on the harbor south side required helical piles in the trail areas where docks will be connected to the trail. Unsuitable subgrade material was removed and replaced to construct a suitable base for the trail. The trail under the bridge required a great deal of steel modification of the sheet piles and connections to get the proper grade and support of the trail.

Users will enjoy wetlands and unique environmental, historical and geological characteristics of the harbor, which early in Tower's history was a bustling commercial center. Interpretive historical signage was installed. Signage describes the harbor as a transportation hub and critical to the development of Lake Vermilion, and the role its waterway played in pioneering Minnesota's unique lake resort identity.

The connecting trail to the Mesabi Trail was rerouted in subsequent design updates to minimize wetland impacts along the shoreline. The revised trail connection will be more cost effective by constructing it with the LCCMR trailhead project, and better supports the goals in protecting and preserving Minnesota's natural resources while trail users enjoy the unique features of the area's geology, plants and wildlife.

PROJECT RESULTS USE AND DISSEMINATION

The public has been informed of this project through local news media coverage of each city council engineering update since 2016. The Lake Vermilion Chamber of Commerce has informed the public on their Facebook page. The page has over 1,000 fans and averages 40,000 contacts per week. The local Timberjay newspaper has informed the public of the project's completion and will provide information on the opportunities for recreational and educational aspects of the project.

Project Completed: 06/30/2019 **FINAL REPORT**

2. M.L. 2015 Projects Completed January 15, 2019 – January 15, 2021

MN Laws 2015, Chapter 76, Section 2

M.L. 2015 Projects

MN Laws 2015, Chapter 76, Section 2 (beginning July 1, 2015)

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

Subd. 03 Foundational Natural Resource Data and Information

County Geologic Atlases - Part B

Subd. 03b $2,000,000 TF

Jim Berg
MN DNR
Ecological and Water Resources Division
Box 25, 500 Lafayette Rd N
St. Paul, MN 55155
Phone: (651) 259-5680
Email: jim.a.berg@state.mn.us
Web: http://www.mndnr.gov

Appropriation Language
$2,000,000 the first year is from the trust fund to the commissioner of natural resources to continue acceleration of the production of county geologic atlases for the purpose of sustainable management of surface water and groundwater resources. This appropriation is to complete Part B of county geologic atlases, which focuses on the properties and distribution of subsurface water found within geologic formations mapped in Part A in order to characterize the potential yield of aquifers and their sensitivity to contamination. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

County groundwater atlases (County Geologic Atlas, Part B) provide information about groundwater to help citizens and organizations improve sustainable management of groundwater resources. Delineated and mapped aquifers, recharge areas, and springsheds are essential information to help guide management decisions.

The county groundwater atlases describe the hydrogeologic setting, water levels, chemistry, pollution sensitivity, and groundwater use in a county. It includes selected hydrogeologic cross sections indicating groundwater flow direction, residence time within aquifers and groundwater-surface water interactions.

Completed county groundwater atlases that were partially funded by this funding include the counties listed below. Some key conclusions include:

Anoka and Sherburne, and Washington counties:
The surficial and upper two to four buried sand aquifers (Anoka; Sherburne and Washington, respectively) are relatively sensitive to pollution. The lower buried sand aquifers and the top of bedrock (Anoka and Sherburne) have large areas that generally appear to be well protected. Elevated chloride and nitrate concentrations in groundwater were found throughout these counties. Elevated concentrations of naturally occurring manganese were detected in more than half of the samples in Anoka and Sherburne.

Nicollet, Sibley, Renville, Wright, and Clay counties:
The pollution sensitivity ratings of the surficial and upper one to three buried sand aquifers (Nicollet,

Sibley, and Renville; Wright and Clay, respectively) are relatively sensitive to pollution. The deeper aquifers have mostly lower pollution sensitivity ratings across the interior of the counties with higher sensi¬tivity ratings in the Minnesota and Mississippi river valleys. Arsenic and manganese are naturally occurring elements of concern that are present in groundwater across these counties.

In Clay County, chemical analysis of groundwater samples indicates groundwater from buried aquifers in the western portion is some of the oldest and most isolated in the state. In Wright and Washington counties, chemical and other evidence shows lake and groundwater connections are common. Future atlases partially funded by this project include: Becker, Brown, Cass, Dodge, Hennepin, Houston, Hubbard, Isanti, Kanabec, Meeker, Morrison, Olmsted, Redwood, Wadena, and Winona counties.

PROJECT RESULTS USE AND DISSEMINATION

We created and presented educational workshops for all of the groundwater atlases that were completed during this funding period. Shorter presentations were also provided to the County Board of Commissioners for most of the completed Part B counties. Short presentations about the DNR part of the atlas program were made to county and other local staff during the completed Part A presentations. Other atlas related presentations included the Benton & Mille Lacs County SWCD, MPCA and non-atlas DNR staff, the Legislative Water Commission, and a state conference of township supervisors.

Technical articles for the Minnesota Groundwater Association (MGWA) for the completed atlases were published in issues of the MGWA newsletter (http://www.mgwa.org/news_letter/newsletter-back-issues/). Public notification of these completions was also provided to over 3000 subscribers through GovDelivery. Paper copies were sent out to the LCCMR Legislative Reference Library. Copies of the atlas are mailed to other interested stakeholders including USGS, local libraries, and state agencies.

Project Completed: 06/30/2018 **FINAL REPORT**

Reintroduction and Interpretation of Bison in Minnesota State Parks

Subd. 03h $600,000 TF

Edward Quinn
MN DNR
500 Lafayette Rd, Box 39
St. Paul, MN 55155
Phone: (651) 259-5594
Email: edward.quinn@state.mn.us
Web: http://www.dnr.state.mn.us/index.html

Appropriation Language
$600,000 the first year is from the trust fund to the commissioner of natural resources to preserve American bison by reintroducing bison to Minneopa State Park and provide interpretive learning opportunities at Blue Mounds and Minneopa State Parks. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

This project helps to preserve the genetics and population of American bison (Bison bison), a species classified as Near-Threatened by the International Union for the Conservation of Nature and provide more and better opportunities for the public to learn about bison and prairie ecosystems. Eleven bison were reintroduced to Minneopa State Park in the fall, 2015. That population has now grown to 20 and

will continue to expand until the population reaches about 40, the carrying capacity for the site. Annual Minneopa park attendance has increased approximately 70% since the bison were introduced. Further evidence of this increase is demonstrated by a 98% increase in annual permit sales compared to pre-reintroduction as well as a 66% increase in daily permit sales. Approximately 1,100 vehicles utilize the bison drive through in the park each week. Tours using the customized "safari" vehicle, which provides visitors with up-close opportunities to view bison and prairie at Blue Mounds State Park were initiated over Memorial Day weekend, 2018. Nearly 1,000 visitors had taken the tour through Labor Day with 98% saying they would recommend it to others. This project has received extraordinary amounts of publicity, from the initial stories posted about the re-introduction which were picked up by over 100 media outlets to continued TV and radio interviews and a MN Lottery spot that should start airing this fall.

PROJECT RESULTS USE AND DISSEMINATION

Information about this project has been shared through a variety of communication tools. Approximately 290,000 visitors to Minneopa are able to experience the bison and prairie ecosystems through interpretive programs, signage and radio broadcast. Another 65,000 visitors to Blue Mounds State Park learn about bison and prairies through programs and signage with approximately 1,000 annually able to participate in "safari" tours out into the prairie for close-ups looks at bison and the prairie ecosystem. Stories about the initial reintroduction at Minneopa were disseminated by over 100 media outlets across the country. The project continues to be highlighted in television and radio interviews. A MN Lottery spot was recently filmed as well as a commercial with Explore Minnesota tourism.

Project due to be completed: 06/30/2019 **FINAL REPORT**

Aquatic and Terrestrial Reptile Habitat

Subd. 03m $250,000 TF

Jennifer McGuire
University of St. Thomas
2115 Summit Ave
St. Paul, MN 55105
Phone: (651) 962-5221
Email: jtmcguire@stthomas.edu
Web: http://www.stthomas.edu/biology/research/biogeochemistry.html

Appropriation Language
$250,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the University of St. Thomas in cooperation with the Three Rivers Park District to analyze the aquatic and terrestrial habitat for certain reptile species in urban lakes and to make specific recommendations to protect and enhance the habitat. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Turtles are among the most threatened organisms in the world, with approximately 61% of the 356 modern species of turtles and tortoises listed as threatened, endangered, or already extinct. Little is known about how human alteration of habitats, including water chemistry in urban lakes, affects turtle behaviors. Human activities can lead to the addition of chemicals such as road salt and excess nutrients,

increased aquatic sediment, and altered water flow patterns. Understanding how these changes affect turtles is critical for appropriate planning to balance human and wildlife needs.

Beginning in the summer of 2015, our team of ecologists, water-quality specialists, wildlife managers and students, conducted research at an urban lake in Plymouth, MN (Medicine Lake) studying population dynamics of Painted Turtles (Chrysemys picta), Snapping Turtles (Chelydra serpentina), and Spiny Softshell Turtles (Apalone spinifera), three of the most widespread native turtle species in North America. We completed:

- Turtle trapping and telemetry of 314 turtles
- Genetic sampling to analyze population size and inbreeding
- Spatial and temporal analysis of lake sediment and water quality
- GIS analysis of turtle home range, habitat use, and water quality

These data were used to prepare recommendations (see final management report for details). Briefly, our data show it is important to protect and conserve diverse natural shorelines (with either sandy or vegetated habitat with locations for basking) to support diverse turtle communities. It is also important to balance human recreational needs with disturbance to basking or nesting sites, particularly for Spiny Softshell turtles that nested on the swimming beach. To maintain high genetic diversity and reduce inbreeding, aquatic connectivity between water bodies should be maintained and preserved. Finally, the impact of road salt should be limited via barriers, as our data show that these chemicals increased in the lake over the four year study, now reaching levels shown to produce aquatic toxicity and impaired food-web dynamics in other systems. Because dissolved salt is nearly impossible to remove from the water, limiting input BEFORE wildlife impacts are observed is critical.

PROJECT RESULTS USE AND DISSEMINATION

Although the work provided here was the subject of academic publications, student projects, and graduate theses (see work plan for additional details), the main results use and dissemination was in providing specific recommendations for future management of Medicine Lake and communicating those to Three River's Park District, the organization managing the lake (see final management plan).

We considered public engagement to be a very important aspect of this project. For social media outreach we created a Facebook page, Turtles of Medicine Lake, with over 150 organic followers. This page was updated with fun facts about the three species of turtles included in this project, relevant new research, and any other project updates that were appropriate. Additionally, we had media coverage from local news channels and local papers throughout the duration of the study. Eric Nelson from Channel 12 Local News and CCX Media filmed and aired a segment in July, 2016. Jeff Edmondson from Kare 11 covered all three years of the project and filmed and aired segments in August of 2016, 2017, and 2018. Sonya Goins from Channel 12 Local News and CCX Media came to the lake to film a segment covering the winter ice dive in March, 2018. And Lastly, Kristen Miller published an article in the Sun Post, also covering the winter ice dive in March, 2018. Bridging the gap between scientific research and the public is one of the most important aspects of science and we were successfully able to this for the Medicine Lake Urban Turtle Study.

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 04 Water Resources

Understanding Water Scarcity, Threats, and Values to Improve Management

Research Project

Subd. 04a $234,000 TF

Bonnie Keeler
U of MN
1954 Buford Ave
St. Paul, MN 55108
Phone: (612) 625-8905
Email: keeler@umn.edu
Web: http://z.umn.edu/keeler

Appropriation Language
$234,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to model and map statewide water scarcity and abundance; assess water-related risks to industry, municipalities, and ecosystems; and quantify the economic values of changes in water quality and quantity in order to inform long-term water sustainability strategies. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

We created high-resolution climate change projections for Minnesota using the best available techniques. State agencies, local governments, private sector engineers, and other climate data users will be able to build freely off the foundational data we have created to make plans that are more prudent for the future of Minnesota. To ensure our results were not sensitive to any one model or year, we averaged the results of five models and further averaged the results over four 20-year scenario periods, 1989-1999 historical, 2040-2059 moderate emissions, and 2080-2099 moderate and high emissions. This gives us confidence that observed changes are the result of long-term changes and not the weather on a single year or model.

The overall trend for the state found in previous global modeling is for a warmer at wetter future. Our work adds local nuance not possible in global models. We find that the timing of precipitation will change, with more precipitation in the spring and early summer, more intense rain events, and longer dry spells between events. The north shore region of the state had the most pronounced increase in both quantity and intensity of precipitation by the end of the century. Infrastructure in the region will have to contend with twice as much precipitation in May, already among the wettest months, and up to 50% more precipitation in the largest 5-day rainfall total in an average year. Corn and soy yields declined by as much as 25% in the majority of scenarios and regions. We also project up to 30 additional days with highs 95°F or hotter.

We also assessed if climate change and increased water withdrawals could lead to water scarcity in the state. We did not find evidence for broad-scale scarcity, but we do highlight watersheds that may consider shifting some of their withdrawals to surface water. We also note that further research is required to capture short-term depletion local effects of withdrawals on surface features.

PROJECT RESULTS USE AND DISSEMINATION

Due to the universal applicability of climate to humans and the environment, we invested extra effort in preparation for disseminating this work. We surveyed practitioners to identify the types of climate data that are most needed to make decisions and manage resources in the state. We have publicized this work in numerous presentations, including the Clean Water Council, the Department of Health, the

Department of Natural Resources and county level managers. We are also working to make much of the underlying data produced as a part of this research readily available to the public. Because the raw data is often challenging for non-specialists to work with, we invested considerable resources in interpreting the results in the accompanying final report.

For scientific audiences, in addition to the underlying data, we are planning three publications and at least one conference presentation based on this work. We already have plans to include these data in other research on irrigation trends and drinking water management in Minnesota.

Finally, as with most of our work, we will write a brief, accessible blog post to highlight and share this work with a broad audience. /p>

Project Completed: 06/30/2018 **FINAL REPORT**

Climate change projections for improved management of infrastructure, industry, and water resources in Minnesota

---

Using Hydroacoustics to Monitor Sediment in Minnesota Rivers

Research Project

Subd. 04g $455,000 TF

Jeffrey R. Ziegeweid
U.S. Geological Survey
2280 Woodale Dr
Mounds View, MN 55112
Phone: (763) 783-3113
Email: jrziege@usgs.gov
Web: http://mn.water.usgs.gov/index.html

Appropriation Language
$455,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the United States Geological Survey to install hydroacoustic equipment on the lower Minnesota and Mississippi Rivers to improve measurement and monitoring accuracy for suspended sediment and enhance ongoing sediment reduction efforts by state, federal, and local agencies. This appropriation is not subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Excessive sediment in rivers degrades water quality, reduces aquatic habitat, increases need for navigation channel dredging, reduces recreational opportunities, and transports harmful contaminants. Lake Pepin, a naturally-formed lake on the Mississippi River, is filling in with sediment at a rapid rate compared to conditions prior to European settlement, and 85-90 percent of the sediment depositing in Lake Pepin comes from the heavily-cultivated Minnesota River Basin. However, we lack detailed spatial information within the watershed to focus sediment-reduction efforts. Therefore, the U.S. Geological Survey (USGS) began a project funded by the Environment and Natural Resources Trust Fund to better understand sources and sinks of sediment in the watershed upstream of Lake Pepin, which includes the Minnesota, St. Croix, and upper Mississippi Rivers. We sampled nine stream locations and developed surrogate relations between newly installed, continuous hydroacoustic sensors and collected suspended sediment samples. Data from this study allows determination of sediment loads for streams in the study

area that are more accurate and at a higher spatial resolution of sampling sites than prior monitoring efforts. Higher gradient river reaches in upstream portions of the study area were consistent sources of sediment. Low gradient areas near river confluences were consistent sinks of sediment, storing more sediment in floodplain or lake environments than was input from upstream. In contrast, mid gradient areas were dynamic, generating sediment load in some conditions but storing sediment in other conditions. Channelized river reaches, latitudinal precipitation patterns, and inputs from sediment-laden tributaries in the southern part of the watershed likely contributed to fluctuating sediment dynamics in mid-gradient areas. The spatial density of continuous sediment monitors was critical to understanding the source/sink dynamics of sediment in the study area. Results of this study may help resource-management agencies target sediment-reduction efforts at areas within the watershed that act as sediment sources.

PROJECT RESULTS USE AND DISSEMINATION

Results of this project will be disseminated in a number of ways. First, suspended sediment data collected at hydroacoustic streamgages in the study area are publicly available on the U.S. Geological Survey (USGS) National Water Information System (NWIS) data portal (https://waterdata.usgs.gov/mn/nwis/sw). Second, real-time suspended sediment data has been made available through the USGS National Real-Time Water Quality website (https://nrtwq.usgs.gov/) for the Minnesota River at Fort Snelling State Park, Minn. (USGS streamgage 05330920), and real-time suspended sediment data will be added for a subset of project streamgages in the near future. Finally, project results will be summarized in a USGS Scientific Investigations Report (Groten and others, in review – draft files attached) that will be publicly-available for dissemination after official publication.

Results of this project have been presented to other agencies, including the U.S. Army Corps of Engineers, the National Weather Service, and the Lower Minnesota River Watershed District; funding through the Environment and Natural Resources Trust Fund has been acknowledged during every presentation given. Furthermore, USGS scientists involved in this project have discussed ways to integrate results of the project into existing cooperative efforts between the USGS and the Minnesota Department of Natural Resources, and the Minnesota Pollution Control Agency (MPCA). Finally, the project chief has been actively involved in discussions with the Upper Mississippi River Basin Association, the Mississippi River Cities and Towns Initiative, and the USGS Midwest Regional Office about ways to integrate project hydroacoustic streamgages into larger regional efforts to improve the health of the Mississippi River.

The results of this study may help the MPCA evaluate progress towards sediment reduction goals for Lake Pepin. For locations that were consistent sources of sediment throughout the study, implementation of best management practices (BMPs) on the landscape may reduce amounts of sediment entering the Minnesota River. However, locations that can change between sources and sinks for sediment likely indicate temporary storage in the Minnesota River and delayed transport to the Mississippi River. The timing and magnitude of in-channel sediment transport in these locations varies substantially with changes in weather and streamflow. Without continuous monitoring of sediment in these dynamic locations, the effects of in-channel sediment transport would be difficult to quantify, complicating efforts to evaluate long-term progress towards sediment reduction goals.

Project Completed: 06/30/2019 **FINAL REPORT**

Study Area Map

Assessment of Irrigation Efficiencies in Benton County

Subd. 04h $431,000 TF

Gerry Maciej
Benton Soil and Water Conservation District
14 Second Ave W
Foley, MN 56329
Phone: (320) 968-5300 x3
Email: gerry@soilandwater.org
Web: http://www.soilandwater.org

Appropriation Language
$431,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Benton Soil and Water Conservation District to develop and implement a decision support system to increase irrigation efficiencies and provide outreach on irrigation best management practices. Software developed with this appropriation must be available in the public domain. Project efforts should be coordinated with the Department of Natural Resources. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Several areas in Minnesota exist where groundwater use exceeds sustainable levels or is approaching a sustainability threshold. One those areas is Little Rock Creek in Benton and Morrison Counties. The overall goal of this project was to provide new tools and expertise to overcome sustainability issues in Little Rock Creek and provide these tools to others facing similar sustainability problems throughout many parts of Minnesota. This project successfully created an online, mobile-friendly, Conservation Irrigation Decision Support System and Irrigation Scheduling Assistant that increases irrigation efficiencies and confidence in irrigation water management. The major outcomes and results from this project include:

1. **Real-Time Conservation Irrigation Decision Support System (CIDSS):** Three DNR monitoring stations on Little Rock Creek were upgraded with satellite telemetry equipment. The CIDSS illustrates real-time graphs of Little Rock Creek's stream flow and temperature along with their associated environmental thresholds. Conservation Irrigation Tips were developed for short- and long-term conservation measures that allows irrigators to make condition appropriate irrigation decisions.
2. **Increasing Irrigation Efficiency:** An online, mobile-friendly irrigation scheduling assistant was created. Input was taken from a local stakeholder group to integrate GIS-based NEXAD daily rainfall estimates into the scheduler that improves field-by-field reliability. We had successful adoption of irrigation water management in the project area. Over the past four growing seasons, irrigation management was practiced on 9,728 acres. In 2018, the software was expanded to a 5-county area of East Ottertail instance, and has been used on 139 fields covering 27,258 acres.
3. **Improving Soil Health:** Technicians provided expertise to producers on soil health practices to increase soil organic matter, conserve soil moisture, and to improve nutrient cycling on the sandy irrigated soils, as well as, reducing wind and soil erosion. A total of 454 acres of soil health practices have been implemented within the project area.

PROJECT RESULTS USE AND DISSEMINATION

This project was able to educate many people about new up-to-date irrigation water management tools. The irrigation scheduling tool and CIDSS for the Little Rock Creek Groundwater Area is available online at

http://ima.respec.com/. The East Ottertail instance that include the 5-county expanded areas of Hubbard, Becker, Wadena, Ottertail and Todd Counties is also available online at http://ima.respec.com/ The project's new online irrigation management scheduler is highlighted on local SWCD's websites, such as www.soilandwater.org and http://www.eotswcd.org/irrigation-scheduler/. A online demo trial of the irrigation scheduler is available to the public to try and to see what the tool has to offer. Promotional banners of the Irrigation Management Assistance were made for the local SWCD's where the current software is offered. Weather station and evapotranspiration data is available at www.agweathernetwork.com. Water flow and stream temperature for Little Rock Creek is currently available to the irrigators using the scheduling assistant within Little Rock Creek Groundwater Area.

Project Completed: 06/30/2019 **FINAL REPORT**

Benton AG: Newspaper Article
Minnesota Irrigator: Newspaper Article

Subd. 06 Aquatic and Terrestrial Invasive Species

Minnesota Invasive Terrestrial Plants and Pests Center

Research Project

Sec. 6a $5,000,000 TF

Sub-Project 07: Tools to Distinguish Native from Exotic Reed Canary Grass - $248,848 TF

Neil O. Anderson
U of M - Department of Horticultural Science
286 Alderman Hall
1970 Folwell Avenue
St Paul, MN 55108
Phone: (612) 624-6701
Email: ander044@umn.edu

OVERALL PROJECT OUTCOME AND RESULTS

The goal of this project was to use molecular markers to determine native vs. exotic reed canary grass status in various locations across Minnesota growing along rivers (Des Moines, Minnesota, Mississippi, Red, Roseau, St. Croix), in fields, as commercially-grown cultivars (forage, ornamental), and preserved historic specimens in herbaria (<1940, presumed native) and a corollary set of samples from rivers in the Czech Republic as exotic comparisons (Activity 1); along MN transportation corridors (highways) existing during the 1920s-1930s (Dust Bowl era) and Minnesota lakes (Bush, Cedar, Como, Phalen, Mille Lacs, Minnetonka, Square, White Bear) and Central Park (Activity 2). Due to Covid-19 travel restrictions, we were unable to get permission to collect along additional lakes. The number of plants analyzed totaled 3,430 (Activities 1,2). Plant DNA was extracted from each sample to determine genomic markers of short DNA sequences (2,889 highly differentiated single nucleotide polymorphisms, SNPs, out of 16,902 total markers) to distinguish native vs. exotic status. Genetic analysis of reed canarygrass showed that river populations are native Minnesota or North American types. Herbarium samples as well those from a native, unplowed field (Roseau, MN) were genetically similar to wild collections from five MN rivers; forage cultivars in commercial fields (Roseau, MN) and along the Roseau River formed a separate group.

The exotic central European populations were distinctly different from all native MN groups. Most variation is within (98.8%), rather than among (1.2%), populations, suggesting little divergence and a high level of shared genetic markers. Across the state, Minnesota rivers had 2-32 genetic variants present, some of which were shared among rivers. Thus, the majority of MN reed canarygrass, while invasive, is native in origin and not exotic (European). Thus, based on this study, all of MN reed canarygrass is native; Tribal and State managers may choose to preserve this species.

PROJECT RESULTS USE AND DISSEMINATION

How has the information from this project been used and/or disseminated?

Dissemination of native vs. exotic status of all Phalaris results from Activity 1 has been reported on the Department of Horticultural Science website (http://horticulture.umn.edu), that of the PIs (http://horticulture.umn.edu/directory/faculty/neil-oanderson), as well as in all PIs/co-PIs Experts at umn.edu links (https://experts.umn.edu/). As many as 11 abstracts were published in national and international meetings, along with corollary public posters sessions or seminar talks to varied audiences of academics, land managers, students, and/or the public-at-large. We have kept State and Tribal Land Managers informed on the native status of MN reed canarygrass and have initiated discussions on approaches to managing this native species yet invasive. The investment by the state on control measures for this invasive grass warrant careful consideration of best management approaches to maintaining the native genetic diversity yet not encouraging the invasive spread of this grass into managed areas. Results were also communicated to the scientific community in peer-reviewed journal articles.

Subproject 07 Completed: 06/30/2020 **FINAL ABSTRACT**

Sub-Project 12: Developing Robust Identification Assays for Amaranthus Palmeri in Seed Mixture - $208,230 TF

Don Wyse
U of M - Department of Agronomy and Plant Genetics
411 Borlaug Hall
1991 Upper Buford Crescent
St Paul, MN 55108
Phone: (612) 625-7064
Email: wysex001@umn.edu
Web: https://agronomy.cfans.umn.edu/department-directory/donald-l-wyse

OVERALL PROJECT OUTCOME AND RESULTS

Palmer Amaranth is an aggressive and prolific weed species that poses a major ecological and economic risk to growers in the state of Minnesota. Closely related to other pigweed species, Palmer has a far more severe impact on agricultural row cropping systems. Early identification of Palmer Amaranth is critical, as it has developed resistance to some of the most widely used herbicides; ALS-inhibitors, PPO-inhibitors, and glyphosate. Visual identification of Palmer Amaranth against other pigweed species is difficult, which has led to the use of genetic testing becoming the standard for identifying Palmer.

To address this emerging challenge we collected at team of weed science experts from the University of Minnesota, Colorado State University and the Minnesota Department of Agriculture. This team developed an improved genetic test to maximize the robustness and reliability of Palmer Amaranth identification for both individual plants and bulk seed screenings. To achieve this, our team collected

Pigweed samples across the United States as well as Mexico, South America and Africa. We extracted DNA samples from a total of 24 populations of Palmer amaranth and 42 non-Palmer pigweeds, resulting in DNA from over 2,000 individual plants. We sequenced more than 800 of these samples through the University of Minnesota Genomic center to search for genetic differences between Palmer and the other species. These differences served as a target for developing a set of genetic markers that can be used for species identification. Once developed the genetic markers were tested against 1,250 pigweed samples to assess their performance.

The final result is a highly reliable test for (>99.7% accuracy) for detecting Palmer Amaranth, both for individual plants and pools of seed. This test will be an important tool for Palmer control for Minnesota growers, crop consultants, and other agronomic specialists. The test is expected to be commercially available in 2020.

PROJECT RESULTS USE AND DISSEMINATION

This project resulted in the development of a robust, highly accurate and easy to use assay for the identification of Palmer Amaranth against other pigweed species. This assay is commercially viable, and a patent was filed for the two markers developed solely at UMN on March 27th, 2020 (Patent #63,000,946). Collaborators at Colorado State University has stated their interest in licensing the tests and offering them as part of a comprehensive Pigweed seed testing service.

This project has also resulted in the creation of a large body of genetic sequence data for Pigweeds assembled from across a wide geographic range. This data will be a valuable resource for future work on Palmer Amaranth and related pigweed species, and will be made publically available through NCBI.

Subproject 12 Completed: 06/30/2020 **FINAL ABSTRACT**

Emerald Ash Borer Ecological/Hydrological Impacts - Phase 2

Research Project

Subd. 06b $400,000 TF

Anthony D'Amato
U of MN
1530 N Cleveland Ave
St Paul, MN 55108
Phone: (612) 625-3733
Email: damato@umn.edu
Web: http://www.forestry.umn.edu/silviclab/index.htm

Appropriation Language
$400,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to assess the potential impacts of emerald ash borer on Minnesota black ash forests and quantify potential impacts on native forest vegetation, invasive species spread, and hydrology. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Emerald Ash Borer (EAB) has been decimating ash trees throughout the Lake States and is currently on the doorstep of the vast acreages of black ash in northern Minnesota. There are over one billion black ash trees in the state and loss of this species is expected to have significant cultural and ecological impacts across the region. This project was a continuation of the Ecological and Hydrological Impacts of

Emerald Ash Borer project that received ENRTF funding in 2010 and was designed to increase our understanding of the vulnerability of northern Minnesota forests to EAB and develop appropriate strategies for increasing the resilience of these critical habitats to the impacts of this introduced insect. Results from this project indicate that loss of black ash will have significant impacts on the hydrology of these areas with overstory mortality resulting in an increased duration of flooding. These impacts are likely to be greatest in swamps occupying depressional or transitional hydrogeomorphic settings. Examination of 32 black ash wetlands across northern Minnesota indicated a region-wide lack of species capable of replacing black ash following EAB and point to an urgent need for active silvicultural intervention to establish non-host tree species in these wetlands. To this end, we monitoring survival of seedlings planted as potential replacement species over a nine-year period and found that the highest surviving species were American elm, swamp white oak, Manchurian ash, and hackberry. Another species showing promise is balsam poplar, which is readily planted from cuttings and may provide an operationally efficient strategy for establishing non-ash tree species in areas threatened by EAB. Collectively, this work has helped identify both the black ash wetlands most vulnerable to EAB impacts, as well as the forest conservation strategies most effective at mitigating these impacts.

PROJECT RESULTS USE AND DISSEMINATION

The results of this project have been shared on numerous occasions with resource professionals, policy makers, citizens, and scientists over the past five years in efforts to inform forest conservation decisions regarding the impacts of emerald ash borer on black ash forests in Minnesota. These dissemination activities have included the development of case studies within the Great Lakes Silviculture Prescription Library highlighting key outcomes of this work. In addition, we have shared the results from this project with private forest landowners, and county, state, tribal and federal natural resource managers on numerous occasions, including through two Sustainable Forestry Education Cooperative webinars (September 15, 2015 and October 17, 2017) and presentations at the Upper Midwest Great Lakes Landscape Conservation Cooperative North Woods Work Group meeting at Sault St. Marie, MI June 28, 2016, and the Society of American Foresters National Convention in Madison, WI on November 3, 2016. The results of this work have also been shared directly with the Silviculture Program Coordinator for the Minnesota DNR to discuss ways in which the findings from this project can inform black ash management guidelines for the state of Minnesota (February 16, 2017). We co-organized the workshop, “Science and Management of Ash Forests after EAB” in Duluth, MN July 25-27, 2017 where results from this project related to hydrology and understory vegetation and associated management strategies were presented to over 200 resource managers, policy makers, and scientists from across MN, MI, WI and the northeastern US. Results of this project related to management strategies for minimizing emerald ash borer impacts were presented as part of the National Silviculture Workshop in Bemidji, MN May 21-23, 2019. This included a field tour for natural resource managers to the sites established under Phase I of this project with representation from the Minnesota DNR, several MN County Land Departments, Chippewa National Forest, Superior National Forest, Division of Resource Management for the Leech Lake Band of Ojibwe, as well as foresters and scientists from across the US. The results of this project related to potential replacement species for planting to sustain the functioning of black ash wetlands following EAB were shared as part of a webinar “Integrating Assisted Migration into Adaptation Strategies for Northeastern Forests.” This webinar is part of the Northern Institute of Applied Climate Science Forest Webinar series, with over 120 forest managers viewing the webinar, which is now archived online on YouTube. Finally, the project PI has served on the Minnesota DNR black ash management guideline committee since the inception of this project and has shared project results to influence the current recommendations for managing MN black ash forests in the face of EAB.

Publications resulting from this work are available for download from the USFS Treesearch website. Additional publications from this work that are currently in development will also be posted on this site and shared with LCCMR staff for dissemination.

Project Completed: 06/30/2020 **FINAL REPORT**

Biological Control of Canada Thistle - RESEARCH

Research Project

Subd. 06c $300,000 TF

Roger Becker
U of MN
411 Borlaug Hall, 1991 Upper Buford Cir
St. Paul, MN 55108
Phone: (612) 625-5753
Email: becke003@umn.edu
Web: http://appliedweeds.cfans.umn.edu/

Appropriation Language
$300,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to develop a biological control for Canada thistle, an invasive plant species in Minnesota. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Canada thistle is a serious threat to natural and managed ecosystems in Minnesota. In 1998, the Canada thistle biocontrol stem-mining weevil Hadroplontus litura was introduced into a limited area in Minnesota with a resulting decline in Canada thistle populations. Although showing a preference for Canada thistle, initial host range testing of H. litura revealed that it attacked other native thistles. Before continuing biocontrol efforts with additional H. litura releases in Minnesota, we wanted to clarify whether H. litura would attack thistles native to Minnesota. The two objectives of our research were: 1.) determine whether H. litura could feed, oviposit and complete development on native thistles, and 2.) determine the phenology of native thistles in relation to Canada thistle. In no-choice tests, female H. litura accepted all native thistle species for oviposition and was able to complete development to the adult stage on swamp, field, tall, Flodman's and wavy-leaved thistle. In Hill's and the federally threatened Pitcher's thistle, no adults were found in development tests. However, since more than half of Hill's and Pitcher's thistle plants died during the course of the experiment and it is unclear whether the plants died as a result of H. litura attack or other causes. Delayed spring emergence on native thistles could temporally escape H. litura oviposition and afford some protection from H. litura. However, all tested native thistles could be attacked because they have shoots present when H. litura eggs are laid in the spring. In conclusion, we recommend that tests should be conducted in open field conditions to document the ecological host range of H. litura prior to the continued released of H. litura as a biocontrol agent of Canada thistle in Minnesota.

PROJECT RESULTS USE AND DISSEMINATION

The following materials were disseminated and produced:

- Becker, R.L. 2017. Update included as part of a broader presentation: Overview of Canada Thistle (Cirsium arvense) Management in Minnesota. Iowa Invasive Species Conference. Honey Creek Resort at Rathbun Lake, Moravia, Iowa. March 28 - 29, 2017
- Becker, R. 2018. Update included as part of a broader presentation: Canada thistle in Minnesota Prairies: Now you see it, now you don't. Webinar hosted by MIPN. International audience (Canada and US). 70 participants. Invited talk, of on 4 in a series. Feb 13 2018. Available online https://www.mipn.org/proceedings/restoration-webinar-series/
- Katovich, E., R. Becker, M. Marek-Spartz. 2018. Host Specificity of Hadroplontus litura on native Cirsium Species. Proc. North Central Weed Science Soc. Hyatt Regency, Milwaukee, WI. Dec. 3–6, 2018. Poster (35)
- Katovich ES, RL Becker, M Marek-Spartz, M Chandler, L Van Riper. 2016. Biological Control of Canada Thistle. UMISC. LaCrosse WI Oct 17-19. Poster.
- Marek-Spartz, M., E. Katovich, R. Becker, M. Chandler, and L. Van Riper. 2018. Biological Control of Canada Thistle: Host Range of Hadroplontus Litura on Native Cirsium spp. Presentation at the Upper Midwest Invasive Species Conference. Rochester Convention Center, Rochester MN. Oct. 15-18, 2018.

Project Completed: 06/30/2019 **FINAL REPORT**

Preventing a New Disease of Pines in Minnesota

Research Project

Subd. 06d $371,000 TF

Robert Blanchette
U of MN
1991 Upper Buford Cir, 495 Borlaug Hall
St. Paul, MN 55108
Phone: (612) 625-0202
Email: robertb@umn.edu
Web: http://forestpathology.cfans.umn.edu/default.htm

Appropriation Language
$371,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to establish early detection for heterobasidion, an invasive root rot fungus, and develop efforts to prevent its spread and reduce its impact. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

A new invasive tree disease called Heterobasidion root disease is a serious threat to Minnesota's red and white pines as well as other conifers. It is considered the most economically important disease of pines throughout the Northern temperate regions. In recent years, the pathogen has moved through Wisconsin and is now found on red pine in southeastern Minnesota. New molecular methods to identify the pathogen were developed and are being used to successfully identify the pathogen from field samples. Monitoring disease progression has been initiated and spores of the pathogen appear to be moving into new areas. Finding this disease early is essential so that control procedures can be initiated to limit the spread of this disease. Control methods for Minnesota have been evaluated and

management guidelines were developed in collaboration with the Minnesota Department of Natural Resources. A series of videos on the biology and control of this disease as well as information on our research activities to find biocontrol agents were developed. These educational materials are being widely used by foresters and landowners in Minnesota as well as in other states. Although some control options are available, research was carried out to identify the possibility of new biocontrol methods that could be used. Native fungi that are antagonistic to the pathogen were tested for their potential use as biological control agents. Several were found to be effective and are ready for field testing. This work has helped to limit the spread of this pathogen in Minnesota and has provided new information on potential future biological control methods. The detection protocols that were developed have been found to be very effective for monitoring this pathogen and can now be adapted and used to survey for other invasive forest pathogens that may affect Minnesota's trees.

PROJECT RESULTS USE AND DISSEMINATION

To disseminate important information obtained from the project we developed four videos that explain the identification, biology and management options for Heterobasidion root disease.

- https://www.youtube.com/watch?v=IRO8eLmHqn0
- https://www.youtube.com/watch?v=4woY5IC40RA
- https://www.youtube.com/watch?v=1_B6g45OGWU
- https://www.youtube.com/watch?v=Y7-jU5LzOgA

These videos provide resource managers and the public with needed information to identify the disease and the most current options for control. Collaboration with the Minnesota Department of Natural Resources in making these outreach materials has resulted in their widespread use and they have become an important resource for limiting the spread of this new invasive disease in Minnesota. Other scientific publications from project results are in the process of being published these include:

- Surveys Results for *Heterobasidion irregulare* in Minnesota
- Fungal community analysis of red pine stumps in managed stands across Minnesota
- Antagonistic interactions between basidiomycete fungi and *Heterobasidion irregulare*

Project Completed: 06/30/2019 **FINAL REPORT**

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

Renewable and Sustainable Fertilizers Produced Locally

Research Project

Subd. 07a $1,000,000 TF

Alon McCormick
U of MN
421 Southeast Washington Ave
Minneapolis, MN 55455
Phone: (612) 625-1822
Email: mccormic@umn.edu
Web: http://www.cems.umn.edu

Appropriation Language
$1,000,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Morris West Central Research and Outreach Center and Twin Cities Campus to develop and demonstrate new technologies aimed at enabling renewable and sustainable production of ammonia for fertilizer in a localized manner. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Activity 1 demonstrated that UMN absorbent technology can pave the way to making ammonia sustainably for the farm, using renewable energy and with producing no greenhouse gas emission. This would reduce the environmental impact of Minnesota farms while also providing relief from stringent seasonal demand for ammonia. Numerous engineering and technoeconomic analysis publications and presentations - assisted also by the US Department of Energy ARPA-E - laid the foundation to develop intellectual property and seek potential future partners. For Minnesota farms, it is next most promising to focus on designing a single integrated reactor-separator module, safer and more efficient than to date, able to produce cheaper ammonia at the farm scale. We will next to seek support to pursue this direction to benefit the Minnesota environment.

Activity 2 explored plasma-generated ammonia and nitrates, showing potential for use in hydroponic irrigation streams providing on-demand fertilizer.

Activity 3 technoeconomic and policy analysis examined appropriate siting and planning of distributed ammonia production for the Minnesota agriculture, establishing important case studies that frame the challenge for the future. Data used was from WCROC's existing wind-to-ammonia facility, demonstrating nationally and internationally the important of this nation-leading benchmark, and drawing interest in possible use of WCROC for a future US Department of Energy demonstration.

Activity 4 explored the question of whether hydrochar might be used to help prevent runoff of ammonia and nitrates from fields (in partnership with Prof. Ken Valentas' project).

PROJECT RESULTS USE AND DISSEMINATION

Engineering publications that laid the foundation for intellectual property development. Presentations at major meetings (national and international ammonia and fertilizer meetings) and state, national and international meetings arranged with the UMN Office of Technology Commercialization, to pursue contacts and plans with prospective partners.

Workshops with possible Minnesota stakeholders convened by co-PI Steve Kelley (formerly UMN Humphrey School of Public Affairs; now, though, Minnesota Commerce Commissioner) to learn and address needs of farmers and local utilities.

News features and science outreach to help get the message out and stimulate further inquiries and discussion Website logging progress and literature resources as they grow from the team's work: (https://wcroc.cfans.umn.edu/research-programs/renewable-energy/ammonia)

Project Completed: 06/30/2019 **FINAL REPORT**

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

MSU Moorhead Science Center Restoration & Monitoring

Subd. 08g $527,000 TF

Brian Wisenden
Moorhead State University
1104 Seventh Ave S
Moorhead, MN 56563
Phone: (701) 212-5801
Email: wisenden@mnstate.edu
Web: http://web.mnstate.edu/wisenden

Appropriation Language
$527,000 the first year is from the trust fund to the Board of Trustees of the Minnesota State Colleges and Universities system for Minnesota State University Moorhead in cooperation with the Department of Natural Resources to restore and monitor 160 acres of prairie and riparian habitat and develop and disseminate monitoring protocols. This appropriation is contingent upon the donation of a 60-acre parcel to Minnesota State University Moorhead from the Minnesota State University Moorhead Alumni Foundation and is available until June 30, 2020, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Bluestem Prairie is Minnesota's largest remnant tall grass prairie (6700 acres) comprising lands owned by The Nature Conservancy, Department of Natural Resources and Minnesota State University Moorhead. This project set out to achieve three goals: (1) acquire additional 189 acres of land contiguous with the complex, 100 acres of which were abandoned agricultural field and 89 acres comprised 60 acres of golf course fairways and 29 acres of riparian terrace forest, (2) collaborate with the MN DNR to restore 160 acres of land to tall grass prairie habitat, and (3) engage faculty and students at Minnesota state University Moorhead to monitor changes in the prairie community before, during and after restoration, to enrich undergraduate curricula, develop capacity for personnel interested in restoration biology, and develop and disseminate monitoring protocols for application to future restoration projects. In the five years since June 2015, we have successfully transferred ownership of the 189 acres of land to Minnesota State University Moorhead, restored 160 acres to tall grass prairie community and engaged 10 MSUM faculty, dozens of research students and many hundreds of undergraduates in concepts and practical skills in conservation ecology. This work has resulted in establishment of a customized GIS database at the site, active and ongoing field projects on microbial ecology, small mammal monitoring, comparison of C3 and C4 plant responses, and establishment of a nutrient network site. The results of these projects have been presented at local and regional meetings in the subdisciplines of faculty principle investigators. In addition, the ENTRF-funded prairie restoration project increased interest in the MSUM Regional Science Center as a regional research site for the study of prairie ecology from faculty at North Dakota State University, several of whom have now established long term research projects at the site.

PROJECT RESULTS USE AND DISSEMINATION

Dissemination of project outcomes have been those presented by project faculty and their research groups at meetings of their respective professional communities in geosciences, ecology and management conferences. Dissemination of overall project description, outcomes and application to undergraduate pedagogy is forthcoming. Plans for final paper preparation were delayed by the covid-19 pandemic.

Project Completed: 06/30/2020 **FINAL REPORT**

Improving Community Forests Through Citizen Engagement

Subd. 08h $800,000 TF

Ken Holman
MN DNR
500 Lafayette Rd N
St. Paul, MN 55155
Phone: (651) 259-5269
Email: ken.holman@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$800,000 the first year is from the trust fund to the commissioner of natural resources to design and pilot a program, including grants to communities, to mobilize citizen volunteers to protect, improve, and maintain local forests in communities around the state. Participation is open to any municipality in the state and participating municipalities will be selected through a competitive proposal process that will include representation from both metropolitan and nonmetropolitan areas of the state. Trees planted using this appropriation must be species that are native to Minnesota. A participating municipality must provide a match of not less than 25 percent, up to half of which may be in the form of in-kind support. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Many communities are not prepared to adequately address declining canopy in Minnesota's community forests. Without action, community forests in Minnesota will continue to decline, impacting air, water, public health, and the natural environment. This project is a model to protect and improve Minnesota's community forests.

Environment and Natural Resources Trust Funds assisted 20 (Ada, Aitkin, Arlington, Austin, Duluth, Ely, Fridley, Grand Marais, Hermantown, Hill City, Hutchinson, Mankato, Maple Grove, Marshall, North Saint Paul, Rochester, Saint James, Saint Paul, Shakopee, Winona) communities through engaging citizens in their community forest. Communities expended a total $437,035.98 in grant funds provided by Environment and Natural Resources Trust Fund, Minnesota Department of Natural Resources, and the United States Forest Service's Great Lakes Restoration Initiative. Communities utilized funds to purchase tools for volunteers to engage with their community forest, such as pruning shears for small tree pruning and binoculars to monitor for emerald ash borer. Communities also used funds to reforest areas of their communities planting 5,631 trees. These trees, maintained by volunteers for the next five years will intercept 1,328,922 gallons of stormwater and reduce 580,016 pounds of carbon dioxide from the atmosphere. Communities worked with partners to implement citizen engagement plans by hosting volunteer planting events, utilizing citizens for small tree pruning, monitoring the health of community trees, and conducting community tree inventory garnering a total of 10,518 volunteer hours.

PROJECT RESULTS USE AND DISSEMINATION

Volunteer engagement training manuals (Appendix B, Appendix C), developed by the University of Minnesota, are tailored to meet the unique community forestry needs of individual communities. These training manuals will continue to be utilized as we expand our community forestry volunteer engagement.

Communities and partners utilized social media, community flyering, a television segment, presenting to community volunteer organizations, and newspaper articles to garner volunteer support and promote community accomplishments. Communities have been provided individual accomplishment and impact reports (Appendix A) to share with their citizens and their community leaders. Project impacts are in the process of being incorporated as accomplishments into the Minnesota Forest Action Plan.

In addition to conducting outreach to garner citizen volunteers and promote project impacts, communities have utilized outreach to provide education about community forests to encourage the care of trees.

Project Completed: 06/30/2018 **FINAL REPORT**

Minnesota Tree Steward
Minnesota Citizen Pruner

Subd. 09 Land Acquisition for Habitat and Recreation

Metropolitan Regional Park System Land Acquisition Phase 4

Subd. 09b $1,000,000 TF

Emmett Mullin
Metropolitan Council
390 N Robert St
St. Paul, MN 55101
Phone: (651) 602-1360
Email: emmett.mullin@metc.state.mn.us
Web: http://www.metrocouncil.org/Parks.aspx

Appropriation Language
$1,000,000 the first year is from the trust fund to the Metropolitan Council for grants to acquire at least 133 acres of lands within the approved park unit boundaries of the metropolitan regional park system. This appropriation may not be used to purchase habitable residential structures. A list of proposed fee title and easement acquisitions must be provided as part of the required work plan. This appropriation must be matched by at least 40 percent of nonstate money that must be committed by December 31, 2015, or the appropriation cancels. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

The Metropolitan Council works with the Regional Park Implementing Agencies to protect critical lands and provide recreational opportunities for the Regional Parks System. This $1,000,000 ENRTF project was matched with $666,000 in Council funds and $555,000 in local Agency funds to purchase three properties for the Regional Parks System.

Washington County acquired a 4.5-acre property for Big Marine Park Reserve and a 102-acre property for St. Croix Bluffs Regional Park with partial funding from this project. These properties contain critical habitats including wetlands, hardwoods, mixed forest, open meadow, and oak savanna. St. Croix Bluffs Regional Park previously protected 3,800 feet of St. Croix River shoreline. With the addition of this 102-acre parcel, the park now protects 5,000 contiguous feet of St. Croix River shoreline. Three Rivers Park District acquired a 16-acre property for the Kingswood Special Recreation Feature with funding from this

project. This acquisition protected 850 feet of shoreline on Little Long Lake, one of the few untouched, pristine lakes left in the metropolitan area.

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

PROJECT RESULTS USE AND DISSEMINATION

The Regional Park Implementing Agencies include the ENRTF sign/logo when they install visitor signs for these new park lands. The Agencies acknowledge ENRTF on their websites when appropriate, such as the Three Rivers Park District Kingswood Special Recreation Feature website funding section. In addition, the Metropolitan Council and the Regional Park Implementing Agencies acknowledge ENRTF for any media releases about the acquisitions.

Project Completed: 06/30/2020 **FINAL REPORT**

SNA Acquisition, Restoration, Enhancement and Public Engagement

Subd. 09c $4,000,000 TF

Ann Pierce
MN DNR
500 Lafayette Rd, Box 25
St. Paul, MN 55155
Phone: (651) 259-5119
Email: ann.pierce@state.mn.us
Web: https://www.dnr.state.mn.us/snas/index.html

Appropriation Language
$4,000,000 the first year is from the trust fund to the commissioner of natural resources to acquire at least 350 acres of lands with high-quality native plant communities and rare features to be established as scientific and natural areas as provided in Minnesota Statutes, section 86A.05, subdivision 5, restore and improve at least 550 acres of scientific and natural areas, and provide technical assistance and outreach. A list of proposed acquisitions must be provided as part of the required work plan. Land acquired with this appropriation must be sufficiently improved to meet at least minimum management standards, as determined by the commissioner of natural resources. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Through this appropriation, 519.3 acres were permanently protected as state Scientific and Natural Areas (SNAs). Protected through these parcels are a variety of Minnesota's most unique intact ecosystems that house many of Minnesota's state threatened and special concern species (see the parcel list for specific site details). Proactive landowner outreach took place in 12 strategically prioritized areas, 7 SNA conservation easements were monitored and the SNA Strategic Land Protection Plan gap analysis was refined to identify exceptional plant communities/species that still need protection for SNA to reach its goal of ensuring that Minnesota's natural heritage is not lost from any ecological region of the state.

Habitat restoration and enhancement activities took place across the state on SNAs. Activities included 45 acres of habitat restoration (see restoration evaluations included with final report), 772 acres of invasive species control, 332 acres of woody control, 652 acres of prescribed burning, 102 acres of prescribed haying, site development work at 51 SNAs, completion of 11 Adaptive management Plans and ecological monitoring at 49 SNAs and 1 proposed SNA. Knowledge gained through monitoring will enable managers to improve management of SNAs for the Species in Greatest Conservation Need, state special concern and state/federally threatened and endangered species that call these habitats home.

Outreach activities through this appropriation brought the SNA Facebook page to nearly 5000 page likes and the total monthly reach, for example, in April 2018 was 72,730. The SNA Flickr social media channel facilitated sharing of high quality photos with 67 members sharing over 991 photos. Five "Nature Notes" e-newsletters were delivered reaching over 5,673 subscribers. From March 1, 2017 through February 2018, 99 events were held involving over 990 people. As of June 2018, there were 149 SNA Site Stewards. These stewards submit reports on their observations and assist with management tasks.

PROJECT RESULTS USE AND DISSEMINATION

The SNA website was updated throughout this appropriation as needed, including listings of new volunteer events. Information on SNAs and activities through this appropriation were posted on the SNA Facebook page which achieved nearly 5,000 page likes. Included with this final report is an SNA Facebook Metrics Report from April-June 2018. The SNA Flickr social media channel was used to encourage high quality photo sharing with 58 members sharing 991 photos. Five Nature Notes e-newsletters were delivered during this timeframe reaching over 5,673 subscribers.

Project Completed: 06/30/2019 **FINAL REPORT**

Native Prairie Stewardship and Prairie Bank Easement Acquisition

Subd. 09d $3,325,000 TF

Judy Schulte
MN DNR
1241 East Bridge Street
Redwood Falls, MN 56283
Phone: (507) 637-6016
Email: judy.schulte@state.mn.us
Web: http://www.dnr.state.mn.us

Appropriation Language
$3,325,000 the first year is from the trust fund to the commissioner of natural resources to acquire native prairie bank easements on at least 675 acres, prepare baseline property assessments, restore and enhance at least 1,000 acres of native prairie sites, and provide technical assistance to landowners. Of this amount, up to $135,000 must be deposited in a conservation easement stewardship account. Deposits into the conservation easement stewardship account must be made upon closing on conservation easements or at a time otherwise approved in the work plan. A list of proposed easement acquisitions must be provided as part of the required work plan. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Through this appropriation, 1,107 acres of high quality dry hill, mesic and wet prairies, which house state and federally threatened species, state special concerns species, multiple Species in Greatest Conservation Need and a wide variety of pollinators, were permanently protected through 12 Native Prairie Bank conservation easements (see attached parcel list for more details). Protection efforts, through this appropriation and other Native Prairie Bank appropriations, preserve some of the best remaining native prairie in the state for current and future MN Citizens benefit. These remaining native prairies function at a significantly higher level and provide habitat to more species of insects, birds, reptiles and mammals than reconstructed/restored prairie. Additionally, 12 Baseline Property Reports and 22 monitoring events were completed through this appropriation. Stewardship funds for the 12 closed Native Prairie Bank easements were enrolled into the Conservation Easement Stewardship Account and 3 appraisals were conducted as an easement valuation best management practice.

A total of 221 acres of invasive species control and 909 acres of prescribed burns were completed to improve prairie quality throughout the prairie region of the state. Adaptive Management Monitoring was completed on 14 Native Prairie Banks and specific research was conducted to evaluate the impact of grazing on secretive marsh birds. Knowledge gained through this monitoring and research will help landowners, DNR land managers and partner agencies improve the management of native prairie and wetlands.

DNR Prairie Specialists participated in 7 outreach events, providing prairie protection, restoration and enhancement education. DNR Prairie Specialists also engaged 163 different priority prairie landowners to discuss protection and management options for their property. Ten Prairie Stewardship Plans were written by contractors, approved by DNR Prairie Specialist and provided to the landowners.

PROJECT RESULTS USE AND DISSEMINATION

Ten Prairie Stewardship Plans were written by contractors, approved by SNA Prairie Specialists and provided to landowners. These plans will help guide native prairie landowner's enhancement activities for well over a decade. All outreach activities completed as part of this appropriation had the ENTRF logo present on any documentation or displays.

Attached is the *Waterbird Response to Conservation Grazing in Western Minnesota Tallgrass Prairies* summary of the research conducted through this appropriation to assess impacts of grazing on waterfowl and other wetland and grassland birds. The results of this study will be distributed to members of the conservation community in several ways. Agency and conservation organization staff hold a grazing webinar at the end of every other summer with DNR hosting and covering these results this year. Marissa, the grad student who took lead on this research had a poster at the recent MN Wildlife Society meetings and we will encourage her and/or her graduate advisor Dr Todd Arnold to present the final results at this year's meeting. Last, the information will be shared among Prairie Conservation Plan partners this fall. The information will be useful to DNR and USFWS staff as we continue to write new grazing plans and modify existing plans. As with any good research project, the results of this study point to additional questions that agency staff and researchers can address in the coming years.

Project Completed: 06/30/2019 **FINAL REPORT**

DNR Paper: Waterbird response to conservation grazing in western Minnesota tallgrass prairies

---

Metropolitan Conservation Corridors Phase VIII - Strategic Lands Protection

Subd. 09f $750,000 TF

Robert McGillivray
The Trust for Public Land
2610 University Ave W, Ste 300
St. Paul, MN 55114
Phone: (651) 999-5307
Email: Bob.McGillivray@tpl.org
Web: https://www.tpl.org/our-work/minnesota

Appropriation Language
$750,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with The Trust for Public Land for Phase VIII of the Metro Conservation Corridors partnership to acquire in fee at least 35 acres of high-quality priority state and local natural areas in the metropolitan area, as defined under Minnesota Statutes, section 473.121, subdivision 2, and portions of the surrounding counties. A list of proposed acquisitions must be provided as part of the required work plan. Land acquired with this appropriation must be sufficiently improved to meet at least minimum management standards, as determined by the commissioner of natural resources. Expenditures are limited to the identified project corridor areas as defined in the work plan. This appropriation may not be used to purchase habitable residential structures, unless expressly approved in the work plan. A list of fee title acquisitions must be provided as part of the required work plan. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Located only 30 miles northeast of the Twin Cities in Washington County, Crystal Spring Scientific and Natural Area (SNA) offers the region's 3.3 million residents a close-to-home opportunity to experience unique flora and fauna and beautiful views of the National Wild and Scenic St. Croix River. Acquired and created with help from The Trust for Public Land in 2015, the original 38-acre, state-owned SNA encompasses significant biodiversity, thriving communities of native plants, and habitat for several rare species of birds and plants. The SNA's dramatic geologic features include a scenic waterfall, steep rocky cliffs, a winding cold-water stream, thick old forests, and panoramic views of the National Wild and Scenic St. Croix River.

Utilizing the M.L. 2015 ENRTF MeCC appropriation, The Trust for Public Land acquired an additional 20.98 acres which it conveyed to the Minnesota DNR on October 24, 2018 as an addition to the Crystal Spring SNA. The Crystal Spring SNA Addition North property provides significantly safer public access to the SNA, and the land contains high quality native plant communities and several rare species of birds and plants.

Due to the funding provided by the Environment and Natural Resources Trust Fund as recommended by the Legislative Citizen Commission on Minnesota Resources, and the Reinvest in Minnesota Program (RIM), the 68 acre Crystal Spring SNA is permanently protected and available for all Minnesotans to enjoy.

PROJECT RESULTS USE AND DISSEMINATION
A TPL project website has been created for the Crystal Spring SNA project.

Project Completed: 06/30/2019 **FINAL REPORT**

Metro Conservation Corridors Phase VIII - Priority Expansion of Minnesota Valley National Wildlife Refuge

Subd. 09g $500,000 TF

Deborah Loon
Minnesota Valley National Wildlife Refuge Trust Inc
3815 East American Boulevard
Bloomington, MN 55425
Phone: (612) 801-1935
Email: dloon@mnvalleytrust.org
Web: http://www.mnvalleytrust.org

Appropriation Language
$500,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Minnesota Valley National Wildlife Refuge Trust, Inc. for Phase VIII of the Metro Conservation Corridors partnership to acquire in fee at least 100 acres of priority habitat for the Minnesota Valley National Wildlife Refuge in the metropolitan area, as defined under Minnesota Statutes, section 473.121, subdivision 2, and portions of the surrounding counties. A list of proposed acquisitions must be provided as part of the required work plan. Land acquired with this appropriation must be sufficiently improved to meet at least minimum management standards. Expenditures are limited to the identified project corridor areas as defined in the work plan. This appropriation may not be used to purchase habitable residential structures, unless expressly approved in the work plan. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota Valley Trust was unable to bring any of the potential acquisitions to completion by the grant deadline. Over the course of this grant, we worked with eight landowners interested in considering the sale of their land to us for the Minnesota Valley National Wildlife Refuge (MVNWR). All were priority parcels delineated by the US Fish and Wildlife Service.

- Minnesota Valley Trust completed fee title acquisition on three parcels for the Rapids Lake Unit of the MVNWR. We could not use this ENRTF grant because all three included buildings. Outdoor Heritage Fund (OHF) grants helped acquire two of the properties, along with private funds. The third was acquired with private funds as leverage to the OHF grant.
- The landowner with property in the San Francisco Unit of the MVNWR was not satisfied with the appraised value and unwilling to continue discussions at that time. We anticipate we will be able to resume discussions in the future.
- Minnesota Valley Trust is working with four landowners who expressed interest in possible sales to us for the Jessenland Unit of the Minnesota Valley National Wildlife Refuge. Extended flooding this year has delayed completion of two appraisals. The appraised values on the other two properties were lower than the sellers would consider at this time. Minnesota Valley Trust will continue working with these landowners.

The market is mixed for the various properties we have been pursuing. We were able to close on the properties with buildings, as they can be sMold for residential development and their values have recovered since the recession. But the properties in the floodplain of the Minnesota River have not recovered after dropping in value during the recession. Those landowners are unwilling to sell at the depressed values.

Because we could not complete any acquisitions, Minnesota Valley Trust is returning these grant funds to the ENRTF.

Project Completed: 06/30/2018 **FINAL REPORT**

Subd. 10 Emerging Issues Account

Sub-Project 03: Deer Movement Related to Potential CWD Prion Transmission - $449,557 TF

Christopher S. Jennelle
MN DNR
5463 West Broadway Ave
Forest Lake, MN 55025
Phone: (651) 539-3310
Email: christopher.jennelle@state.mn.us
Web: http://www.dnr.state.mn.us/index.html

OVERALL PROJECT OUTCOME AND RESULTS

We quantified dispersal and migratory movements of wild white-tailed deer (Odocoileus virginianus) in southeastern Minnesota that are relevant to understanding the potential spread of chronic wasting disease (CWD). After detection of CWD in fall 2016 in Fillmore County, we sought to determine potential pathways of CWD spread on the landscape via wild deer movements and estimate general causes of deer mortality in southeastern Minnesota. Since March 2018, we captured and fitted GPS collars to 226 deer and continue to monitor 72 animals. The main causes of mortality were hunting and vehicle collision in the yearling to 3-year-old deer composing our sample, which underscores the importance of harvest management as a valuable tool to control CWD in southeastern Minnesota. Average annual survival for females and males was 0.73 and 0.54, respectively, and these low survival estimates likely reflect effective liberalized harvest regulations within the study area to manage CWD.

We found that 26% of females and 43% of males dispersed between their natal and adult home range, and surprisingly 15% of females and 6% of males underwent seasonal migration between summer and winter ranges. The average dispersal distance for females and males was 20.0 km and 22.8 km, respectively, while that for migratory females and males was 12.8 km and 17.7 km, respectively. We also observed extreme dispersal distances of 116 km and 97 km, respectively, for a female and male. Both sexes tended to disperse westward, although a pattern was unclear for migratory animals. Deer were more likely to avoid agricultural landscape during dispersal and migration, although we did not observe consistent habitat characteristics along movement paths. The southwest to northwest trajectory of dispersal movements underscores increased risk of CWD spread to the Minnesota interior. This information will be vital for prioritizing and guiding CWD management efforts in and around southeastern Minnesota.

PROJECT RESULTS USE AND DISSEMINATION

Over the course of this project, we have had 23 articles, interviews, or media reports pertaining to this study. MNDNR staff have given at least 14 professional presentations regarding this study to state, federal, and University audiences. We have also created a dedicated webpage devoted to providing background and updates to this study. We have outreached to over 250 private landowners in southeastern Minnesota as part of the process of obtaining permission to access private property for deer capture and GPS-collaring efforts. We have provided regular updates and interactive maps to participating landowners, interested citizens, and hunters who have submitted harvested collared deer to us. We are in the process now of creating an interactive map of select study deer to go live on our webpage that will allow the public to better engage with the amazing movement data we have collected

thus far. We have written three DNR agency reports of this project thus far, and are in the process of writing manuscripts for publication. We will continue to collect data for deer with active GPS collars, and we intend to collar about 45 additional deer in early 2021 as a final cohort for this study.

Subproject 03 completed: 06/30/2020 **FINAL ABSTRACT**

3. M.L. 2014 Projects Completed
January 15, 2019 – January 15, 2021

MN Laws 2014, Chapter 226, Section 2

M.L. 2014 Projects

MN Laws 2014, Chapter 226, Section 2 (beginning July 1, 2014)

MN Laws 2014, Chapter 312, Article 12, Section 8 (beginning July 1, 2014)

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

Subd. 06 Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Enhancing Pollinator Landscapes

Subd. 06a $864,000 TF

Marla Spivak
U of MN
219 Hodson Hall, 1980 Folwell Ave
St. Paul, MN 55108

Phone: (612) 624-4798

Email: spiva001@umn.edu

Web: http://beelab.umn.edu/

Appropriation Language
$864,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to identify sources of nectar and pollen for native pollinators and honey bees and coordinate ongoing and future efforts to enhance pollinator habitat and opportunities for pollinator nesting and foraging. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Pollinators play a key role in ecosystem function and in agriculture, including thousands of native plants and more than one hundred U.S. crops that either need or benefit from pollinators. However, pollinators are in dramatic decline in Minnesota and throughout the country. The causes of the decline are not completely understood, but identified factors include loss of nesting sites, fewer flowers, increased disease, and increased pesticide use. Fortunately, there are known actions that can be taken to help counteract some of these factors. Researchers at the University of Minnesota are using this appropriation to conduct efforts aimed at increasing reliable supplies of nectar and pollen for pollinators by surveying for existing populations, identifying plants that contribute the most resources to pollinator production and survival, and identifying areas where pollinators nest and overwinter. Information will be used to develop maps, demonstration sites, best management strategies, and long term plans for sustaining pollinators that will assist private landowners and public land managers in efforts to enhance landscapes for the benefit of pollinators.

OVERALL PROJECT OUTCOME AND RESULTS

There is a large knowledge gap regarding the distribution, floral preferences, habitat use, and nesting ecology of the more than 400 native bee species in Minnesota. This funding provided the first important and comprehensive step to fill this gap. For Activity 1, the University of Minnesota hired Dr. Daniel Cariveau in September 2015. Since starting as an Assistant Professor, Dr. Cariveau has built a large, highly productive lab group focusing on native bee ecology and conservation. This includes five graduate

students, three postdoctoral research associates, four full-time research staff and over 20 undergraduate research technicians. He has raised over $3 million in state and federal funds and has published seven manuscripts in that time. He has also helped organize projects throughout the state and has built relationships with MNNDR, Pheasants Forever, MNDOT, USFWS, and The Nature Conservancy. For the second activity we collected over 10,000 specimens of 268 species and verified the identity of over 13,000 specimens and nearly 350 species from historic collections. We have thus documented the current and past distribution and abundance of Minnesota's native bees. This provides critical baseline data that will inform native bee conservation. For the third activity, we compiled data on over 45,000 native bee by plant interactions. We sampled bees in urban and prairie ecosystems. We have used these collections to develop lists of plants for habitat and these data have generated research into minimizing restoration costs. In the fourth activity, we documented how plant species and management activities influence nesting of stem-nesting bees. This work is a critical step as most research addresses only floral use by bees. The results of this work can be used by homeowners to better manage nesting habitat. We are in the process of publishing results in peer-reviewed journals. Data will be open access upon publication.

PROJECT RESULTS USE AND DISSEMINATION

Using this funding we were able to reach a wide array of audiences. For one, we held a total of four organizational symposia that focused on ongoing pollinator work being funded by the Environmental and Natural Resources Trust Fund. At these symposia, individuals with projects funded through ENRTF discussed the scope, results and importance of their findings. A major goal of these symposia was to prevent overlap and encourage collaboration. Therefore, we also held break-out sessions at these meetings and discussed new project ideas along with how to share results from current research. These symposia typically involved 15 – 20 presentations with 30-50 participants. Staff and LCCMR members attended a number of these symposia. In addition, we presented nearly 30 outreach talks and 3 scientific presentations that focused on the research being conducted from this proposal. Some of these talks included large audiences and were broadcast widely, such as interviews with the Minnesota Public Radio. In addition, we also spent the summer of 2017 managing a novel, multi-tiered mentorship program. Drs. Cariveau and Rodgers mentored two University of Minnesota undergraduate students. These students received their own funding through the Undergraduate Research Opportunity Program at the University of Minnesota. In addition, the City of Minneapolis recruited two Urban Scholars to participate in sampling. The Urban Scholars program provides mentorship and funding to undergraduate students from diverse backgrounds to conduct scholarly work with the City of Minneapolis. Drs. Cariveau and Rodgers also recruited a Step-Up student. The Step-Up program is aimed at providing internships to high school students that experience barriers to employment. Finally, we created an outreach document titled Nesting Habitat for Stem Nesting Bees. All of the content of this document is compiled and the design is being finalized.

Project Completed: 06/30/2019 [Extended in M.L. 2015, Chapter 76] **FINAL REPORT**

Dredged Sediment for Forest Restoration on Unproductive Minelands

Subd. 06j $300,000 TF

Marsha Patelke
U of MN - NRRI
5013 Miller Trunk Hwy
Duluth, MN 55811

Phone: (218) 788-2642

Email: mpatelke@d.umn.edu

Web: http://www.nrri.umn.edu

Appropriation Language

$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota-Duluth for the Natural Resources Research Institute to restore up to 136 acres of unproductive mine stockpile while improving the treatment of municipal sewage and biosolids near Virginia using clean Erie Pier dredged sediment and managed forestry techniques. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

Project Overview

Mine stockpiles are unproductive due to soil deficiencies of organic matter, nutrients, and soil organisms, which are essential to supporting healthy plant growth, diversity, and succession. Waste products, including biosolids, composts, and dredged materials, have the potential to be used to address some of these deficiencies and make the lands productive again. Researchers at the Natural Resources Research Institute at the University of Minnesota in Duluth are using this appropriation to demonstrate and evaluate methods for using dredged sediment and treated biosolids as a substrate for restoring up to 136 acres of unproductive minelands to productive forestland. If effective this technique could be applied more broadly to minelands in Minnesota and elsewhere with potential benefits including production of materials for the biofuels and forest products industries, increased wildlife habitat, restoration of unproductive lands, and re-utilization of waste products.

OVERALL PROJECT OUTCOME AND RESULTS

This project investigated using sediment dredged from the Duluth-Superior Harbor for enhancing mineland restoration, beyond what is required by state reclamation requirements, and to demonstrate potential economic gain from purpose-grown trees for biofuel. Funding was provided by ENRTF. The NRRI secured supplemental funding from the U.S. Army Corp of Engineers and the U.S. Department of Commerce to support transport of 4,500 cubic yards of dredge material to the Virginia, Minnesota landfill project site.

The Virginia Landfill property was cleared of existing vegetation in 2015 and three study plots were constructed, totaling approximately 4.5 acres. Dredge material was applied in two of the plots at 6-inch and 12-inch thicknesses; the remaining plot (control) did not receive sediment. Cottonwood, Tamarack, and White Pine were planted in 2017 and 2018.

Major project tasks included: counting surviving trees and measuring their heights; soil fertility sampling; and floristic inventories of all plants. For comparison purposes, tree-planting success at two sites previously treated with dredge sediment was also evaluated.

Tamarack had the lowest survival rate and White Pine had the highest, regardless of the plot. Cottonwood were more successful in the sediment plots than in the control. Average tree heights ranged from less than a foot to 2.5 feet at the project site, while high mortality and inconsistent growth rates were observed at the two comparison sites.

The economic potential from purpose-grown trees cannot be estimated with so short a growing time. Trees require 20 to 90 years' growth to attain a marketable height of 40 to 50 feet. Consequently, the greater near-term value of applying dredge material to disturbed or mined land is associated with

shortening the time it takes to establish good vegetative cover. Based on the study results and observations, creating pollinator habitat could be another beneficial dredge material use.

PROJECT RESULTS USE AND DISSEMINATION

Results from this project, including soils and vegetation data were shared with St Louis County Environmental Services (2017), Minnesota Department of Natural Resources Mineland Reclamation program (2019), and United Taconite personnel (2019).

Project Completed: 06/30/2019 **FINAL REPORT**

Subd. 07 Land Acquisition, Habitat, and Recreation

Metropolitan Regional Park System Acquisition

Subd. 07b $1,500,000 TF

Emmett Mullin
Metropolitan Council
390 N Robert St
St. Paul, MN 55101

Phone: (651) 602-1360

Email: emmett.mullin@metc.state.mn.us

Web: http://www.metrocouncil.org/Parks.aspx

Appropriation Language
$1,500,000 the second year is from the trust fund to the Metropolitan Council for grants for the acquisition of lands within the approved park unit boundaries of the metropolitan regional park system. This appropriation may not be used for the purchase of habitable residential structures. A list of proposed fee title and easement acquisitions must be provided as part of the required work program. This appropriation must be matched by at least 40 percent of nonstate money that must be committed by December 31, 2014, or the appropriation cancels. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

The Twin Cities area is host to a nationally renowned system of regional parks and trails that provides numerous outdoor recreational opportunities for the public while preserving green space for wildlife habitat and other natural resource benefits. Currently the regional parks and trails system consists of 51 parks and park reserves containing more than 54,000 acres, more than 300 miles of interconnected trails, and has more than 46 million visits each year. Through an existing grant program, the Metropolitan Council is using this appropriation to partner with local metropolitan communities to partially finance the acquisition of approximately 200 acres to be added to existing metropolitan regional parks. Priority will be given to lands with shoreland, lands that provide important natural resource connections, and lands containing unique natural resources.

OVERALL PROJECT OUTCOME AND RESULTS

The Metropolitan Regional Parks System is a natural resource-based system, with an emphasis on lands that are contiguous to lakes, rivers, or other water bodies. Natural resource protection and restoration

is a key objective for the system. The 2014 ENRTF appropriation of $1.5 million was matched with $1 million of Metropolitan Council bonds and $833,000 of regional park implementing agency funds for a total of $3.3 million for acquisition for the Regional Park System. Approximately 114 acres were acquired through this appropriation. The parcels acquired contain high quality natural resources and are located within the boundaries of regional parks, regional park reserves or regional trails.

Nine properties were acquired for the Regional Park System. Dakota County acquired a 2.5-acre inholding for the Lebanon Hills Regional Park that will be restored to oak savanna. Washington County acquired an 8-acre hardwood forest inholding for the Big Marine Park Reserve that includes a portion of Pitzl Pond.

Three Rivers Park District acquired three properties totaling 19.6 acres for the Rush Creek Regional Trail. Rush Creek runs through these properties and these acquisitions will protect .75 miles of shoreline along with the creek's wetlands and uplands.

Three Rivers Park District also acquired two properties totaling 65 acres for the Baker Carver Regional Trail. One of these properties contains wetlands, woods, and a creek that feeds into Lake Minnetonka and Minnehaha Creek. The other property contains uplands with mature trees, and nearly 3 acres of wetland with frontage on Six Mile Creek.

Finally, Three Rivers Park District acquired two properties totaling 18.5 acres for the West Mississippi Regional Trail. These properties contain wooded ravines and a half mile of shoreline, protecting the Mississippi River along the regional trial.

These nine acquisitions will add over 100 acres to the Regional Park System for all Minnesotans to enjoy, while protecting valuable natural resources for the region.

PROJECT RESULTS USE AND DISSEMINATION

The three Regional Parks Implementing Agencies that acquired property through this project- Dakota County, Three Rivers Park District, and Washington County- each conducted their own dissemination activities. Washington County issued a news release after acquiring the property for Big Marine Park Reserve and posted an ENRTF sign at the site. Dakota county also posted an ENRTF sign at the property acquired for Lebanon Hills Regional Park, and they had significant public attention and engagement while updating their Master Plan and developing a new Natural Resource Management Plan for the park. Three Rivers Park District acquired 7 properties and issued news releases for each one and will be posting signs as the properties become accessible to the public. The news releases for each property are included in the Work Plan Final Report.

Project Completed: 06/30/2019 [Extended in M.L. 2018, Chapter 214] **FINAL REPORT**

Invasive Terrestrial Plants and Pests Center

Research Project

Sec. 08 $1,460,000 TF

Rob Vennette
U of M - Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC)
1992 Folwell Avenue
Saint Paul, Minnesota 55108

Phone: (612) 301-1405

Email: venet001@umn.edu

Web: http://www.mitppc.umn.edu/

Appropriation Language
$490,000 in 2015 is from the environment and natural resources trust fund for the Invasive Terrestrial Plants and Pests Center requested under this act, including a director, graduate students, and necessary supplies. This is a onetime appropriation and is available until June 30, 2022.

$970,000 from the environment and natural resources trust fund appropriated in Laws 2011, First Special Session chapter 2, article 3, section 2, subdivision 9, paragraph (d), Reinvest in Minnesota Wetlands Reserve Acquisition and Restoration Program Partnership, is transferred to the Board of Regents of the University of Minnesota for the Invasive Terrestrial Plants and Pests Center requested under this act, including a director, graduate students, and necessary supplies and is available until June 30, 2022.

Project Overview

Terrestrial invasive species are species that are not native to a location and that pose critical ecological and economic challenges once they become established in that location. They come in the form of plants, animals, insects, pathogens, and microbes that can cause harm to natural habitat, urban landscapes, and agricultural systems. The problems posed by terrestrial invasive species continue to grow as existing infestations expand and new exotic species arrive, many of which are poorly understood. New ideas and approaches are needed to develop solutions and to stay on top of emerging threats. The University of Minnesota is using this appropriation to help launch a new interdisciplinary Terrestrial Invasive Species Research Center charged with using scientific findings to support policy-making, application, and resource management practices that address the terrestrial invasive species affecting Minnesota. The center will coordinate initiatives focused on prevention of establishment, early detection and rapid response, development of new control methods and technology, integrated pest management, and minimizing non-target impacts of control. Proven tools and techniques developed at the center are intended to be implemented statewide as applicable.

Sub-Projects M.L. 2014, Sec. 08:

- *01: Metagenomic approaches to develop biological control strategies for aquatic invasive species* - $299,363
- *02: Attracting carp so their presence can be accurately assessed* - $682,269
- *03: Common carp management using biocontrol and toxins* - $384,231
- *04: Developing and evaluating new techniques to selectively control invasive plants phase I: manipulating sunfish to enhance milfoil weevils and factors influencing selective herbicide control of curlyleaf pondweed* - $194,415

Project Completed: 06/30/2022 **Work Plan**

Sub-Project 01: Novel Diagnostic Tools for Rapid and Early Detection of Oak Wilt - 271,911 TF

Dr. Abdennour Abbas
U of M - Minnesota - MITPPC
2004 Folwell Avenue
Kaufert Lab, Rm# 203
Saint Paul, Minnesota 55108

Phone: (612) 624-4292

Email: aabbas@umn.edu

Web: https://www.abbaslab.com

OVERALL PROJECT OUTCOME AND RESULTS

Oak trees (Quercus spp.) play a significant role in the ecosystem and are considered economically important for several reasons. They are prone to oak wilt disease, caused by the fungus, Bretziella fagacearum, which is of huge concern due to the reduced profitability in their production. Affected trees cannot be cured and so, early, and rapid identification of the infection is necessary to prevent spreading. The objectives of this study include the development of cell separation method of woodchips and DNA extraction method, followed by the development of a rapid detection assay in combination with a handheld system. Infected and healthy red oak wood chip samples were collected from different parts of Minnesota followed by DNA extraction and testing using the chemiluminescence-based chemical assay. In phases I and II of this project, we developed a novel Nanoparticles Enhanced Chemiluminescence (NEC) assay. The major accomplishments include: (1) Combination of the DNA extraction protocol with NEC assay detection. (2) Application of the NEC assay on real-world samples (wood chips from healthy and infected red oak trees) and determination of the sensitivity (88.8 %) and specificity (73%) of the NEC assay. (3) Optimization of the reaction conditions. Additionally, MITPPC phase III proposal has been approved to expand the NEC assay to various invasive forest pathogens of high priority to Minnesota and conduct third party validation of the technology. The major impact of this project will be the improvement of diagnostic capabilities of plant diagnostic clinics and laboratories by offering a highly sensitive and cost-effective tool for rapid identification of oak wilt. The spread of the disease can be stopped at an early stage by administering treatments and implementing preventative measures. The proposed technology will help protect Minnesota natural resources and reduce the financial burden of oak tree removal.

PROJECT RESULTS USE AND DISSEMINATION

The research findings were disseminated through regular updates to the Minnesota Invasive Terrestrial Plants and Pests Center, non-peer reviewed outlets (e.g., newsletters or websites), and peer-reviewed publications. This project was also discussed through formal and informal presentations to stakeholder groups and scientific societies.

Subproject 01 Completed: 06/30/2020 **FINAL ABSTRACT**

Sub-Project 02: Early Detection, Forecasting and Management for Halyomorpha halys - $420,535 TF

William Hutchison
U of M - Minnesota - MITPPC
1980 Folwell Avenue

219 Hodson Hall
Saint Paul, Minnesota 55108

Phone: (612) 619-1775

Email: hutch002@umn.edu

Web: https://www.fruitedge.umn.edu/pests/bmsb

OVERALL PROJECT OUTCOME AND RESULTS

Oak trees (Quercus spp.) play a significant role in the ecosystem and are considered economically important for several reasons. They are prone to oak wilt disease, caused by the fungus, Bretziella fagacearum, which is of huge concern due to the reduced profitability in their production. Affected trees cannot be cured and so, early, and rapid identification of the infection is necessary to prevent spreading. The objectives of this study include the development of cell separation method of woodchips and DNA extraction method, followed by the development of a rapid detection assay in combination with a handheld system. Infected and healthy red oak wood chip samples were collected from different parts of Minnesota followed by DNA extraction and testing using the chemiluminescence-based chemical assay. In phases I and II of this project, we developed a novel Nanoparticles Enhanced Chemiluminescence (NEC) assay. The major accomplishments include: (1) Combination of the DNA extraction protocol with NEC assay detection. (2) Application of the NEC assay on real-world samples (wood chips from healthy and infected red oak trees) and determination of the sensitivity (88.8 %) and specificity (73%) of the NEC assay. (3) Optimization of the reaction conditions. Additionally, MITPPC phase III proposal has been approved to expand the NEC assay to various invasive forest pathogens of high priority to Minnesota and conduct third party validation of the technology. The major impact of this project will be the improvement of diagnostic capabilities of plant diagnostic clinics and laboratories by offering a highly sensitive and cost-effective tool for rapid identification of oak wilt. The spread of the disease can be stopped at an early stage by administering treatments and implementing preventative measures. The proposed technology will help protect Minnesota natural resources and reduce the financial burden of oak tree removal.

PROJECT RESULTS USE AND DISSEMINATION

The research findings were disseminated through regular updates to the Minnesota Invasive Terrestrial Plants and Pests Center, non-peer reviewed outlets (e.g., newsletters or websites), and peer-reviewed publications. This project was also discussed through formal and informal presentations to stakeholder groups and scientific societies.

Subproject 02 Completed: 06/30/2019 **FINAL ABSTRACT**

Sub-Project 03: Climate Change and Range Expansion of Invasive Plants - $206,335 TF

David Moeller
U of M - Minnesota - MITPPC
1479 Gortner Avenue
140 Gortner Laboratory
Saint Paul, Minnesota 55108

Phone: (612) 624-1037

Email: moeller@umn.edu

Web: https://moellerlab.wordpress.com/

OVERALL PROJECT OUTCOME AND RESULTS

In our project, 'Climate change and range expansion', our goal was to use public records of species presences and available environmental data to build models that predicted the habitat suitability and invasion risk under current and future climate scenarios for 10 invasive species of interest to MN. Those species were: Common Tansy, Wild Parsnip, Palmer Amaranth, Oriental Bittersweet, Narrowleaf Bittercress, Japanese Hops, Common Teasel, Dalmatian Toadflax, Brown Knapweed, and Black Swallowwort. We originally planned to include Grecian Foxglove, but were unable to obtain enough data to build reliable models. We developed species distribution models (SDMs) using multiple techniques (Maxent, Boosted Regression Trees, and Joint Distribution Modeling of Communities) and multiple scales (North American continent and Upper Midwest) to validate results. We wrote a report with detailed finding from our SDMs titled, “Species Distribution Model Projections for Incipient Invasive Species of Minnesota”. Our findings can be used to help guide management decisions about surveillance and eradication efforts for these species. Additionally, we have published on our findings on methods for producing accurate models of invasive species and specific SDMs for the species of interest in academic peer-reviewed journals. We have also presented our work at the UMISC-NAISMA and Palmer Amaranth Conferences and have participated as presenters in USFS land manager training. The project supported or trained one postdoctoral scholar, one postgraduate research assistant, two undergraduate students, and one graduate student. One undergraduate student decided to continue as a graduate student working on invasive species and is an author on all of the manuscripts and data products. The management document and all of the underlying data, models, and projections are archived at the Data Repository for U of M (DRUM) and are freely available to Minnesotans to access to gain a better picture of the potential distributions of the listed species.

PROJECT RESULTS USE AND DISSEMINATION

Our project has resulted in four publications, five major presentations to disseminate our findings at national and regional meetings, and 80 data products that can be accessed by all Minnesotans and natural resource professionals. We have published our SDM results for Palmer amaranth in the open-access journal Scientific Reports, which is freely available to the public. We have presented the result of this paper at the UMISC-NAISMA Joint Conference in Oct 2018 in the Palmer amaranth session to scientists and professionals interested in the problem of rapid, invasive spread of Palmer amaranth. We also presented to work as a poster at the first MITPPC Palmer Amaranth Summit in Jan 2019 and Dr. Briscoe Runquist participated in the conference management working groups as scientific expert on the biology and potential for spread of the species. We have also presented this work to the MN NWAC Management and Policy Subcommittee. Additionally, we provided training to US Forest Service professionals about the underlying mechanics of species distribution models and how and when they can be used to effectively forecast and manage the spread of invasive species under current and future climate conditions. Lastly, we produced a document specific to predicted habitat suitability in MN to be used by MN natural resource professionals for surveillance and eradication decision-making. This document will be housed with the MITPPC in hard copy form and will be accessible as a pdf on their website for download.

During the course of this project, we have generated 80 multi-layered data products that have been archived at the Data Repository for U of M (DRUM) with DOI numbers that can be used to quickly access the data. These data products can be used for further analyses for researchers and natural resource professionals. For each of the species, we have collated a list of occurrence records (current through

2018) that are sourced from multiple databases and have been cleaned for problematic records. They are ready for use in multiple applications that require verified occurrence data. We have also generated multiple SDMs, their validation metrics, and current and future projections based on these models for all ten species. We have provided the models and the raster projections for these SDMs as downloadable files. Further, for 3 species, Narrowleaf Bittercress, Oriental Bittersweet, and Japanese Hops, we developed Joint Species Distribution models (JSDMs) to compare with traditional SDMs using DNR relevé data, environmental data, and a Bayesian method for joint attribute modeling. The input data (climate data, species co-occurrence matrices) and output data (models and projections) are also available for use. These models provide data on projections for the invasive species, as well as for other potential plant community members of interest.

Subproject 03 Completed: 06/30/2019 **FINAL ABSTRACT**

Report on Palmer Amaranth in Scientific Reports

Sub-Project 04: Cover It Up! Using Plant to Control Buckthorn - $327,000 TF

Peter Reich
U of M - Minnesota - MITPPC
1530 Cleveland Avenue
Saint Paul, Minnesota 55108

Phone: (612) 624-4270

Email: preich@umn.edu

Web: https://forestecology.cfans.umn.edu

OVERALL PROJECT OUTCOME AND RESULTS

Buckthorn is an invasive shrub that outcompetes native plants and degrades Minnesota forests. Removal of buckthorn is a common management activity but often only provides short-lived benefits since buckthorn rapidly re-establishes. In grasslands, heavily seeding native species can often restore native communities and inhibit invasion, but this approach is rarely used in forest management (Schuster et al. 2018). We investigated whether we could similarly establish enough native plants to prevent buckthorn from re-establishing in forest using three separate experiments.

First, we surveyed sites at 24 properties in Minnesota where buckthorn management had taken place to identify the most successful techniques (Wragg et al. in review). Management success was highly variable, but sites where more native vegetation had been re-established tended to have lower buckthorn abundance.

Second, we measured the growth and survival of buckthorn seedlings in a forest biodiversity experiment. There, we found that canopies that permitted less than 10% of incoming light had significantly reduced buckthorn growth and canopies that permitted less than 3% light, particularly in the spring and fall, completely excluded buckthorn (Schuster et al. 2020).

Third, we established a series of experiments across 7 sites that had recently had buckthorn removed. In those experiments, we tested how densely seeding or planting native plants affected buckthorn seedlings. After 3 years, we found that planting trees and shrubs, particularly Sambucus shrubs, greatly reduced light levels and excluded buckthorn (Wragg et al., Schuster et al. in prep). Other seeding and planting treatments had more moderate effects and may require additional years to become fully

effective. We also found that the rarely-used herbicide fosamine ammonium was effective at controlling buckthorn (Schuster et al. in review).

The Cover It Up! project illustrates that it is possible to curate native plant communities in a way that makes them resistant to buckthorn invasion. In general, we recommend that forests be managed to promote the establishment of shrubs and trees that provide heavy shade in the spring and fall. Our findings suggest that by doing so, managers can simultaneously increase forest health, inhibit invasion, and reduce the need for investment in future buckthorn removals.

PROJECT RESULTS USE AND DISSEMINATION

Results were disseminated through diverse media to a wide range of stakeholders. Findings from Cover It Up! were included in five academic journal articles to date. Stories about our project were featured in media from unaffiliated parties, including KARE 11, Pioneer Press, National Park Service social media, and Science Museum of Minnesota Field Notes. Our findings were also conveyed through 12 in-person presentations for over 500 attendees.

Subproject 04 Completed: 06/30/2019 **FINAL ABSTRACT**

4. M.L. 2013 Projects Completed
January 15, 2019 – January 15, 2021

MN Laws 2013, Chapter 52, Section 2

M.L. 2013 Projects

MN Laws 2013, Chapter 52, Section 2 (beginning July 1, 2013)

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

Subd. 06 Aquatic and Terrestrial Invasive Species

An Aquatic Invasive Species Research Center

Research Project

Subd. 06a $8,700,000 TF

Nicholas Phelps
U of M - Minnesota Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 624-7450
Email: phelps083@umn.edu
Web: https://www.maisrc.umn.edu/

Appropriation Language
$4,350,000 the first year and $4,350,000 the second year are from the trust fund to the Board of Regents of the University of Minnesota to develop and support an aquatic invasive species (AIS) research center at the University of Minnesota that will develop new techniques to control aquatic invasive species including Asian carp, zebra mussels, and plant species. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

Project Overview

Aquatic invasive species pose critical ecological and economic challenges for the entire state and beyond. They can cause irreparable harm to fisheries and aquatic habitat as well as damage to infrastructure. The problems posed by aquatic invasive species continue to grow as existing infestations expand and new exotic species arrive, most of which are poorly understood. New ideas and approaches are needed to develop real solutions. In 2012 the Minnesota Legislature provided the University of Minnesota with $3,800,000 ($2,000,000 from the Environment and Natural Resources Trust Fund; $1,800,000 from the Clean Water Fund) to launch a new, first-of-its-kind research center specifically focused on developing and implementing solutions to control aquatic invasive species. This appropriation provides this new center with additional initial operating funds for conducting research aimed at slowing the spread, reducing, controlling, and/or eradicating aquatic invasive species including Asian carp, zebra mussels, Eurasian watermilfoil, and more. Proven tools and techniques developed at the center are intended to be implemented statewide.

OVERALL PROJECT OUTCOME AND RESULTS

This project successfully established the Minnesota Aquatic Invasive Species Research Center (MAISRC) at the University of Minnesota, a vibrant and durable research program that develops research-based solutions to Minnesota's aquatic invasive species (AIS) problems. MAISRC has quickly become a global leader in the field and a go-to resource for managers, the public and researchers. In total, 32 subprojects were supported from this project – significantly advancing our scientific understanding and ability to manage AIS. New tools have been developed and knowledge gaps filled on many of Minnesota's most

important AIS, including: zebra mussels, bigheaded and common carps, starry stonewort, non-native Phragmites, Eurasian watermilfoil, curlyleaf pondweed, Heterosporosis, and spiny waterflea. The results of this work have been broadly disseminated to end-users via research reports, peer-reviewed manuscripts, fact sheets, white papers, news media, newsletters and presentations (on the MAISRC website). An annual Research and Management Showcase has been held since 2014, with 700+ unique attendees in total. MAISRC has also created an award-winning and sustainable citizen science program ("AIS Detectors") that has trained hundreds of people from across the state. This project supported efforts to ensure effectiveness and efficiency of a Center-based research model, including a 10-year strategic plan, a comprehensive process for prioritizing research needs, increased collaboration and coordination between researchers and managers, an annual competitive and peer-reviewed request for proposals, the formation of external and internal advisory boards, research dissemination and outreach, support of a world class research facility, and creation of communication and development plans. Minnesota is much better equipped to address our AIS problems than we were prior to this project – MAISRC has significantly advanced the science of AIS management and engaged thousands of stakeholders and partners from across the state and world. This project will continue with Phase II and III appropriations awarded in 2017 and 2019.

PROJECT RESULTS USE AND DISSEMINATION

MAISRC currently has a social media following of just under 2,300 and an e-newsletter list with just under 3,500 recipients. Social media posts about research findings, events, AIS Detector workshops, and general invasive species news are posted daily. An e-newsletter goes out every other month and includes more in-depth stories about our research projects. In addition, MAISRC has recorded consistent growth in the number of unique visitors and total website views since the website launch in February 2016. This increase shows that MAISRC is growing in name recognition and being seen as an important resource for different stakeholders around the state. Over the course of the last six years, MAISRC has been in approximately 350 news stories in roughly 117 different outlets. The most common outlets have been the Star Tribune¸ Minnesota Public Radio, and KSTP-TV. Other notable outlets include The New York Times, The Washington Post, and Minnesota Bound. Nine videos were created highlighting MAISRC subproject research. Six AIS Research and Management Showcases were held with 700+ unique attendees. The AIS Detectors program was formally launched in March 2017 and we now have 299 certified Detectors around the state.

- The nine videos highlighting MAISRC subproject research included:
  - AIS Detectors
  - Starry stonewort research
  - Spiny waterflea research
  - Impacts of AIS on walleye
  - Using pathogens to control invasive carp
  - Novel methods for controlling common carp
  - Valuing AIS management
  - Genetic control of invasive carp
  - Using the Whooshh fish transport system (not released yet)

Sub-Projects M.L. 2013, 06a:

- *02: Metagenomic approaches to develop biological control strategies for aquatic invasive species* - $299,363
- *03: Attracting carp so their presence can be accurately assessed* - $682,269
- *04: Common carp management using biocontrol and toxins* - $384,231

- *07: Developing eradication tools for invasive species Phase II: Virus Discovery and evaluation for use as potential biocontrol agents* - $445,210
- *08: Aquatic Invasive Species Research Center Sub-Project 8: Risk assessment, control, and restoration research on aquatic invasive plant species* - $822,000
- *09: Population genomics of zebra mussel spread pathways, genome sequencing and analysis to select target genes and strategies for genetic biocontrol.* - $427,950
- *10: Citizen Science and Professional Training Programs to Support AIS Response* - $566,550
- *12: Characterizing spiny water flea impacts using sediment records* - $207,766
- *14: Cost-effective monitoring of lakes newly infested with zebra mussels* - $266,500
- *16: Sustaining walleye populations: assessing impacts of AIS* - $198,700
- *17: Building scientific and management capacity to respond to invasive Phragmites in Minnesota* - $246,800
- *18: Eurasian and hybrid watermilfoil genotype distribution in Minnesota* - $221,375
- *19: Decision-making tool for optimal management of AIS* - $172,465
- *21: Early Detection of Zebra Mussels Using Multibeam Sonar* - $96,549
- *26: Updating an invasive and naitve fish passage model for locks and dams* - $90,827

Project Completed: 06/30/2019 **OVERALL FINAL REPORT**

Sub-Project 02: Metagenomic approaches to develop biological control strategies for aquatic invasive species - Phase II: Development of Potential Microbiological Control Agents for Aquatic Invasive Species - $299,363 TF

Michael J. Sadowsky
U of M - Minnesota - Aquatic Invasive Species Research Center
140 Gortner Lab, 1479 Gortnet Avenue
St. Paul, MN 55108

Phone: (612) 624-2706

Email: sadowsky@umn.edu

Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

Aquatic invasive species (AIS), including Eurasian watermilfoil (EWM) and zebra mussels (ZMs) pose a serious threat to the health and function of aquatic ecosystems. Traditional approaches for AIS management, including use of chemicals and manual removal, have been ineffective. This requires development of new management and eradication strategies, such as the use of (micro)biological control agents. Some microorganisms have evolved to live in close association with aquatic organisms and such relationships could be exploited to develop microbe-mediated AIS management strategies. As the first step towards the identification of potential biocontrol strategies, microbial communities associated with 'healthy' AIS were compared with that of 'diseased' AIS or to native species. Since no natural diseased mussels were available, we opted to develop an experimental model system, which allowed for the application of different intensities of stress – heat (17, 25, 33℃) and salinity (1.5, 13.5 ppt), to promote the proliferation of opportunistic pathogens. High-throughput DNA sequencing of 414 samples (providing 32 million DNA reads) resulted in the identification of several potentially 'pathogenic' microbial groups that were strongly associated with ZM mortality. These included Aeromonas,

Chryseobacterium, Flavobacterium, Acidaminobacter, Clostridiaceae 1 sp., Rhodobacteraceae sp., Acinetobacter, Shewanella, and Clostridium sensu stricto 13. For the identification of EWM-specific microbiota, high-throughput DNA sequencing was performed on 315 samples (46 million reads) derived from leaf and root compartments of EWM and six native macrophyte species. This resulted in the identification of taxa that were significantly enriched in EWM leaves and roots compared to native plants. Though several AIS-associated microorganisms were isolated that could be pathogenic to invasive mussels (e.g. Aeromonas) - none of them met our safety requirements for further testing. Future studies must isolate and evaluate the efficacy of 'host-specific and pathogenic' biocontrol candidates that will only infect invasive mussel species.

PROJECT RESULTS USE AND DISSEMINATION

Our research findings were disseminated via oral and poster presentations at the following (international/ national/ local) conferences: 61st International Association for Great Lakes Research conference (Toronto, Canada), UNC Water Microbiology Conference 2019 (Chapel Hill, NC), 20th International Conference on Aquatic Invasive Species (Fort Lauderdale, FL), 5th Upper Midwest Invasive Species Conference (Rochester, MN), 119th General Meeting of the American Society for Microbiology (San Francisco, CA), and the AIS Research Management Showcase in 2017 & 2018 (St. Paul, MN). Two papers were published in the journals 'FEMS Microbiology Ecology' and 'Science of the Total Environment' during this project period. One manuscript is currently undergoing peer-review and two additional manuscripts are under preparation. All sequencing data generated in this project will be publicly available (via submission to NCBI Genbank) and all publications will list accession numbers to link to short read archive of all samples. Thus far, all sequence data mentioned in current publications is directly linked to a publicly available web site for download.

Subproject 02 Completed: 06/30/2019 **FINAL REPORT**

Sub-Project 03: Attracting carp so their presence can be accurately assesed - $682,969 TF

Peter Sorensen
U of M - Minnesota Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 624-2706
Email: sadowsky@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

This project developed several tools that can manage and control all species of invasive carp species in Minnesota. First, we developed ways using both food and sex pheromones to attract and measure the presence and density of carp using the environmental DNA (eDNA) they release to the water. This technique is superior to traditional netting because it can be performed in any habitat or water of any depth, including at low densities that are otherwise unmeasurable. eDNA can also determine carp gender. Second, we developed a deterrent system comprised of sound, light and air curtain that is 97% effective in the laboratory and could safely and effectively prevent invasive carp from swimming upstream through navigation locks in Mississippi River. If this deterrent system were to be paired with attractant-based eDNA surveillance methods in specific lock-and-dams whose gate was also adjusted to stop carp, it is extremely likely that enough carp could be prevented from passing through these lock-

and-dams that the remainder could be removed by targeted commercial fishing. Field tests of the deterrent system are now underway.

PROJECT RESULTS USE AND DISSEMINATION

The first invasive carp deterrent system in the world is now in place in southern Minnesota using the sensory cues we identified. The USGS is now exploring the pheromone and food attractants we developed in the Great Lakes, and the sound/light stimuli we developed are being used at Barkley Dam in Kentucky by the UAFWS with whom we have partnered with. Sorensen and colleagues have at 5 peer-reviewed scientific publications in high quality journals and several technical reports. A PhD and a MS thesis are being produced. A dozen talks were given as part of this project.

Subproject 03 Completed: 06/30/2019 **FINAL ABSTRACT**

Sub-Project 04: Common carp management using biocontrol and toxins: Phase II - $384,231 TF

Przemyslaw Bajer
U of M - Minnesota Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 625-6722
Email: bajer003@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

This project aimed to test new management tools for the common carp, Minnesota's most abundant invasive fish. We used a whole lake experiment to test if bluegill sunfish can reduce production of carp fry in shallow lakes (Activity 1). We also used a series of lab, pond and lake experiments to test if corn-based food pellets that contain a toxin can be used to selectively target carp without harming native fish (Activities 2, 3, 4). Activity 1 (bluegill experiment in 6 small lakes) showed that bluegills can suppress the production of carp fry in shallow lakes by 8-fold. Thus, maintaining healthy bluegill populations in lakes would serve as an important biocontrol strategy for carp in Minnesota.

Activities 2, 3, and 4 showed that common carp readily consume corn pellets that contain a toxin (Antimycin-A, ANTA) and cannot distinguish between pellets with or without the toxin. Further, in a pond experiment with carp and three native species (white sucker, bluegill, yellow perch), only carp ate the toxic pellets and perished. Finally, in a natural lake experiment where we tagged nearly 500 carp and 900 native fish, only carp were attracted to corn-based pellets (we did not use toxin in the lake experiment). This was further verified using underwater cameras. Overall, corn-based food pellets appear to be very powerful and relatively species-specific attractant for carp. Toxins, such as ANTA, could be incorporated into such pellets to target carp. Our work also showed that corn (without toxin) can be used as bait to train carp to form large feeding aggregations that could be targeted using simpler and safer means than toxins, such as nets.

Future directions might include: 1) Focusing on risks and costs associated with using corn-based pellets that contain ANTA or other toxins to control common carp, 2) Focusing on how baiting with corn can be used to induce large feeding aggregations of carp than could be removed with nets. This is being addressed in Phase III.

PROJECT RESULTS USE AND DISSEMINATION

Information collected in these experiments were disseminated and will continue to be disseminated in a variety of ways. Presentations were given at MAISRC showcases, the Minnesota and National American Fisheries Society meetings, and will be given at the International Conference for Invasive Species.

Two manuscripts have been published:

- Poole, J. R., Sauey, B. W., Amberg, J. J., & Bajer, P. G. (2018). Assessing the efficacy of corn-based bait containing antimycin-a to control common carp populations using laboratory and pond experiments. Biological Invasions, 20(7), 1809-1820.
- Poole, J. R., & Bajer, P. G. (2019). A small native predator reduces reproductive success of a large invasive fish as revealed by whole-lake experiments. PloS one, 14(4), e0214009.

One manuscript has been submitted for publication:

- Hundt, P. J., Amberg, J. J., Sauey, B. W., & Bajer, P. G. 2019. Toward a new Common Carp (Cyprinus carpio) management tool: Laboratory and mesocosm experiments testing a species-specific corn-based bait containing a toxin. Submitted to Management of Biological Invasions

Subproject 04 Completed: 06/30/2017 **FINAL REPORT**

Assessing the efficacy of corn-based bait: Paper

Sub-Project 07: Developing eradication tools for invasive species Phase II: Virus Discovery and evaluation for use as potential biocontrol agents - $445,210 TF

Dr. Nicholas Phelps
U of M - Minnesota Aquatic Invasive Species Research Center
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 624-7450
Email: phelp083@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

One possible component to an effective integrated pest management plan for aquatic invasive species would be through the introduction or promotion of species-specific pathogens. This high-risk, high-reward approach must be carefully assessed with thorough investigation and scientifically justified risk assessment. In Phase II of this long-term effort, we characterized the virome invasive and native fish species and zebra mussels. We achieved our ultimate goal of this project and identified a candidate virus (koi herpes virus) that caused high mortality in common carp and was not detected in native fish species – this virus will be the focus of Phase III. We also identified many other novel and undescribed viruses in health and dead fish, however the implications of these results are unknown and warrant additional research to better understand the threat to native species and/or potential as biocontrol agents. The virome of zebra mussels was also interesting with lower viral diversity than the fish species investigated; however, no viruses emerged as potential zebra mussel biocontrol candidates from field samples or laboratory trials.

This study emphasized the value of advanced molecular approaches to unbiased viral discovery and diagnostics. The methods we developed and optimized for sample collection, processing, and sequence analysis (all together called a 'pipeline'), have informed testing protocols at the Minnesota Veterinary Diagnostic Laboratory. We have also elevated awareness among managers that viral diversity is much higher than currently known and deserves more attention as early indicators of potential threats.

The project team spent considerable time during Phase II engaging with managers, scientists, and the public in multiple formats. It is important that this type of research is transparent and understandable to all stakeholders. To that end, we held formal in person meetings, attended local-national-international scientific conferences, published a peer-review manuscript, networked with internationally-renowned experts, produced two videos, and provided interviews for print, radio and TV media.

PROJECT RESULTS USE AND DISSEMINATION

We had learned during Phase 1 of this project (MAISRC Sub Project 7.1) that communication, outreach and transparency were very important for this type of project. To that end, the project team has spent considerable time engaging with managers, scientists, and the public in multiple formats. This has included formal in person meetings, local-national-international scientific conferences, peer-review publication, networking with internationally-renowned experts, video production, and print, radio and TV media. A summary of this is listed below:

Formal in-person meetings: Great Lakes Fish Health Committee, MN DNR Koi Herpes Virus Working Group.

Scientific conferences: American Fisheries Society – Fish Health Section, Eastern Fish Health Workshop, MAISRC showcase (x3), International Conference on Aquatic Invasive Species, Minnesota Veterinary Diagnostic Laboratory, Aquatic Invaders Summit III, Freshwater Mollusk Conservation Society, International Symposium on Aquatic Animal Health. NOTE: Most of these conferences were supported by non-LCCMR funding.

Peer-review publication: Padhi, S. K., I. E. Tolo, M. McEachran, A. Primus, S. K. Mor, N. B. D. Phelps. In press. Koi herpesvirus and carp edema virus: Infections and coinfections during mortality events of wild common carp in the United States. Journal of Fish Disease. Several other publications are in progress.

Networking with experts: Dr. Ken McColl, Dr. Tom Waltzek, Dr. Mikolaj Ademek, and others.

Video production: Video 1 (viewed 822 times as of 8/8/19), Video 2 (viewed 96 times as of 8/8/19).

Media: New York Times, KSTP 5, KARE 11, Star Tribune, Minnesota Daily, MN DNR Press release, MAISRC newsletters.

Subproject 07 Completed: 06/30/2019 **FINAL REPORT**

Sub-Project 08: Aquatic Invasive Species Research Center Sub-Project 8: Risk assessment, control, and restoration research on aquatic invasive plant species - $822,000 TF

Daniel J. Larkin
U of M - Minnesota Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 625-6350
Email: djlarkin@umn.edu

Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

Aquatic invasive plants can lower native plant diversity, reduce habitat quality for fish and other animals, and interfere with recreation. To protect Minnesota's water resources, steps need to be taken to prevent new invasions, control existing populations, and support recovery of native biodiversity. These efforts require sound, science-based guidance. To provide such support, we conducted research to predict invasion risk, assess ecological impacts, evaluate control efficacy, and investigate factors limiting post-control recovery of native aquatic plants. This work was applied to three target species at different stages of invasion: (1) Nitellopsis obtusa (starry stonewort), first found in Minnesota in 2015 and now known in 14 lakes; (2) Myriophyllum spicatum (Eurasian watermilfoil), found in 1987 and established in >300 lakes; and (3) Potamogeton crispus (curly-leaf pondweed), here for >100 years and in >750 lakes. For starry stonewort, we developed models to predict risk of further spread and prioritize search locations for statewide volunteer search efforts, experiments to determine how long starry stonewort remains can survive out of water (i.e., remain transportable by boaters), and field and lab-based control experiments to guide management. For Eurasian watermilfoil and curly-leaf pondweed, we investigated relationships with native plant biodiversity, finding that they displace native species, an effect compounded by lower water clarity, and contribute to "biotic homogenization"—loss of ecological distinctiveness. We are investigating how to better control these invasive species and foster recovery of native vegetation by synthesizing thousands of aquatic plant surveys and management records collected in Minnesota and by conducting in-lake removal and restoration experiments. This work will continue under a follow-up project (MAISRC Subproject 8.2: Impacts of invader removal on native vegetation recovery). Our findings help Minnesotans by highlighting practices needed to protect lake ecosystems and refining approaches for preventing invasions, reducing populations of established AIS, and restoring native species.

PROJECT RESULTS USE AND DISSEMINATION

Information from this project has been disseminated through 10 peer-reviewed journal articles, 30 invited talks, 20 contributed presentations, 45 media stories, and resources published on the MAISRC website. Fully published articles (7 of the 10) are included as attachments. Project findings are being used to guide AIS spread prevention and management efforts involving the Minnesota Department of Natural Resources, lake associations, and other stakeholders. This project has also contributed significantly to MAISRC Subproject 10 ("Citizen Science and Professional Training Programs to Support AIS Response").

Subproject 08 Completed: 06/30/2019 **FINAL REPORT**

Lake and Reservoir Management Article: Response of the invasive alga starry stonewort *(Nitellopsis obtusa)*..
Journal of Aquatic Botany Article: Biology, ecology, and management of starry stonwort *(Nittellopsis obtuse;* Characeae)..
Journal of Ecology Article: Environmental filtering and competitive exclusion..
Realized niche shift associated with the Eurasian charophyte *Nitellopsis obtusa* becoming invasive in North America
Forecasting distributions of an aquatic invasive species *(Nitellopsis obtusa) under future climate scenarios*

Sub-Project 09: Population genomics of zebra mussel spread pathways, genome sequencing and analysis to select target genes and strategies for genetic biocontrol - $380,318 TF

Michael A. McCartney, Ph.D.
U of M - Minnesota Aquatic Invasive Species Research Center
Dept of Fisheries, Wildlife and Conservation Biology, 135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 626-1412
Email: mmccartn@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL SUBPROJECT OUTCOME AND RESULTS

Since arriving in Duluth Harbor in 1989, zebra mussels have infested more than 150 inland lakes and 17 rivers and streams in MN, with rising ecologic and economic costs. Efforts to block new invasions must be focused strategically on major sources of spread. To help achieve this, we used direct, forensic-like analyses to genetically identify waters from which mussels were carried to infest MN lakes. Using our new genome sequences and methods, we genetically classified mussels from more than 70 water bodies, with more than 6,000 DNA markers per mussel (compared to 9 markers/mussel in Subproject 9.1) – providing significantly increased clarity in the analysis. We found that lakes in the Detroit Lakes, Brainerd and Alexandria regions form large, unique genetic clusters found nowhere else. Additionally, mussels from the Mississippi and St. Croix Rivers, Lake Superior, and Lake Minnetonka (4 highly-likely source waters) are distinguishable from the clustered invasions with 6,000 genomic markers, but with our previous analysis of 9 markers, they were not. More research is needed across a larger, more regional landscape to determine the original sources of zebra mussels into MN, but results reinforce the management message that prevention can work – there is no genetic information to support the hypothesis of a “super spreader” lake. Early and high profile infestations of zebra mussels appear to have been contained (e.g. Lake Millle Lacs). However, vectors that are moving mussels locally within lake-rich regions, need to be identified and blocked.

For the first time, we sequenced the entire zebra mussel genome, using state of the art technology that allowed mapping of genes to chromosomes with great confidence. We sequenced and measured expression of genes in tissues that control shell formation, byssal thread attachment, and survival in high temperatures—each are strong candidates for targeted gene modification. The results include a publicly accessible genome: a powerful tool for invasion biology and biocontrol researchers in MN and worldwide.

SUBPROJECT RESULTS USE AND DISSEMINATION

The results from this project were regularly communicated in presentations to public and professional audiences. McCartney delivered a total of 14 public presentations on research activities and outcomes at non-scientific meetings and events, and authored or co-authored a total of nine presentations on results of this work at professional conferences, meetings, and invited seminars, including talks at the University of MN Duluth, University of Montana Flathead Lake Biological Station, Montana Fish Wildlife and Parks, and the University of Iowa. As intended in the dissemination plan, outreach was accomplished at local, state and national levels with public talks in Douglas, Hubbard, Itasca, Meeker, Otter Tail, and Stearns Counties in MN, two in Wisconsin, two in Montana and one in Iowa. Media attention on this project was high and resulted in three print news items, including two front-page feature articles in the Minneapolis Star Tribune. A highlight was two podcasts by Montana Public Radio in which both the population genomics of spread and the genome sequencing projects were covered in

detail. Our research was regularly communicated in newsletter articles posted on the MAISRC website. Information about the zebra mussel genome project in the form of a white paper, written originally for a professional audience of scientists and managers in multiple disciplines (Activity 3), but accessible to members of the public with some background in AIS1. Two publications are in process (titles below)—one in revision2 and the other to be submitted soon. Two other manuscripts are in preparation, one on invasion genomics (Activity 1), and the other reporting on sequencing and analysis of the zebra mussel genome (Activities 2 and 3). All Next Generation Sequence data from Activities 1 and 2 will be publicly available in the MAISRC Data Repository at the University of MN or the National Center for Biotechnology Information database.

- McCartney, M.A., Mallez, S., Gohl, D. and K. Beckman (2018) The zebra mussel genome project: developing a new resource for invasion biology and biocontrol research. A white paper available from the author.
- McCartney, M.A., Mallez, S., Gohl, D. and K. Beckman (in revision) Genome projects in invasion and conservation genetics research programs. *Conservation Genetics*
- Mallez, S. and McCartney, M.A. (in prep) Moving zebra mussels into the 'omics' era: SNPs from NGS-based genotyping outperform microsatellites in discerning invasion sources. *Ecology and Evolution*

Subproject Completed: 12/31/2018 **FINAL REPORT**

The zebra mussel genome project

Sub-Project 10: Citizen Science and Professional Training Programs to Support AIS Response - $566,550 TF

Daniel Larkin
U of M - MN Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 625-6350
Email: djlarkin@umn.edu
Web: http://larkinlab.cfans.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

Early detection of invasive species is critical. However, there are few professionals addressing aquatic invasive species (AIS) in MN relative to our state's vast water resources. Furthermore, while many efforts each year seek to control AIS, there are gaps in synthesizing treatment outcomes. These gaps limit our ability to improve management and contribute to uncertainty for lake associations and others tasked with management decision-making. We developed AIS citizen science and training programs to address these challenges. Specifically, AIS Detectors trains volunteers as "eyes on the water" for AIS detection and response, and AIS Trackers educates non-professionals on AIS management and leverages monitoring data to refine management guidance. Over 820 MNns have participated; more have been reached through presentations, media, and publications. To date, 299 people have become certified AIS Detectors and gone on to contribute >10,000 hours to outreach, stewardship, citizen science, and other volunteer activities, a service value >$273,000. Outgrowths of Detectors have led to additional service, including "Starry Trek", which annually draws ~200 volunteers statewide for targeted searches for the

invasive alga starry stonewort. This event, in partnership with the MN DNR and colleagues from Wisconsin, has led to identification of two new starry stonewort populations and associated opportunities for rapid response; over 500 people have participated. Through AIS Trackers, we developed a new online course to educate people about AIS management and new mechanisms for analyzing AIS treatment outcomes. Over 70 people have piloted this program, which will open in 2020 to a wide audience in MN and beyond. MNns benefit from our work through enhanced capacity for AIS surveillance and robust training that helps professionals and non-professionals alike make better-informed management decisions. Results show that natural resources benefit when we empower MNns to contribute to AIS prevention efforts through rigorous, science-based training and service programs. These programs are now well-established and will continue to be implemented under support from MAISRC, UMN Extension, and program revenue.

PROJECT RESULTS USE AND DISSEMINATION

Information from our project has been disseminated through 2 publications (attached), 16 invited talks, 11 contributed presentations, 5 webinars, 69 media stories, and online resources. This project has also contributed significantly to MAISRC Subproject 8 ("Risk assessment, control, and restoration research on aquatic invasive plant species").

Subproject 10 Completed: 06/30/2019 **FINAL REPORT**

Journal of Extension: Flipping the Classroom to Train Citizen Scientists in Invasive Species Detection and Response

---

Sub-Project 12: Characterizing spiny water flea impacts using sediment records - $212,266 TF

Donn Branstrator
U of M - Duluth
1035 Kirby Drive, 207 SSB
Duluth, MN 55812
Phone: (218) 726-8134
Email: dbranstr@d.umn.edu
Web: https://scse.d.umn.edu/biology-department/faculty-staff/dr-donn-branstrator

OVERALL PROJECT OUTCOME AND RESULTS

Although aquatic invasive species threaten MN's environment, economy, and recreation, we still know little about the colonization histories and ecosystem impacts of some of the state's invaders such as spiny water flea. This project made large advances in understanding the colonization and impact of spiny water flea in Lake Mille Lacs, Lake Kabetogama, Lake Winnibigoshish, and Leech Lake through the collection and analysis of organism remains in lake bottom sediments over about a 120 year period from present (2017 or 2018) back to the year 1900. The results provide replicated evidence that spiny water flea was resident continuously in Lake Mille Lacs and Lake Kabetogama since the 1930s, or about 80 years before it was first detected in the open waters of either lake. Evidence demonstrates that spiny water flea had a prolonged history of low abundance in both lakes before about the year 2000 at which time it began to increase rapidly. Zooplankton that are prey and competitors of spiny water flea often declined in abundance after spiny water flea increased in abundance. There was no evidence of spiny water flea in the sediments of Lake Winnibigoshish. There was evidence of a small population of spiny water flea in the sediments of Leech Lake that dated to the year 2001, possibly representing a failed

invasion. To date, Leech Lake has never been known to contain this organism. The data allow us to test hypotheses about the timing and impact of spiny water flea on the food webs of MN lakes. The results re-cast our understanding of the timeline of spiny water flea invasion in MN and underscore the value of lake sediments to study invasive species. The results suggest that traditional methods of spiny water flea detection with nets, as carried out by academic units and management agencies in MN, may be inadequate to detect spiny water flea when it is low or transient in abundance.

PROJECT RESULTS USE AND DISSEMINATION

We have disseminated our project results at a variety of conferences and meetings as summarized below:

- MAISRC Research & Management Showcase (St. Paul, MN) – two platform presentations (September 12, 2016)
- MAISRC Research & Management Showcase (St. Paul, MN) – four laboratory presentations (September 12, 2016)
- Coe College Wilderness Field Station (Ely, MN) – platform presentation (July 22, 2017)
- MAISRC Research & Management Showcase (St. Paul, MN) – two platform presentations (September 13, 2017)
- MAISRC All Members meeting (St. Paul, MN) – platform presentation (November 28, 2017)
- MAISRC Science-In-Seconds competition (St. Paul, MN) – platform presentation (May 30, 2018)
- MAISRC Research & Management Showcase (St. Paul, MN) – poster presentation (September 12, 2018)
- Upper Midwest Invasive Species Conference (Rochester, MN) – poster presentation (October 15-18, 2018)
- Association for the Sciences of Limnology and Oceanography Conference (San Juan, Puerto Rico) – poster presentation (Feb 23 – Mar 2, 2019)
- Rainy-Lake of the Woods Watershed Forum Conference (International Falls, MN) – poster presentation (March 13-14, 2019)
- MN Department of Natural Resources meeting (St. Paul, MN) – skype presentation (May 14, 2019)

We have included images of two poster presentations that were displayed at science conferences.

Subproject 12 Completed: 06/30/2019 **FINAL REPORT**

Sub-Project 14: Cost-effective monitoring of lakes newly infested with zebra mussels - $266,500 TF

John Fieberg
U of M - MN Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108

Phone: (612) 301-7132
Email: jfieberg@umn.edu
Web: https://fieberg-lab.cfans.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

The current lack of standardized methods for surveying zebra mussels during their earliest stages of lake colonization limits our ability to track changes in density over time or to evaluate effectiveness of treatment programs (e.g., as required by DNR permits). We evaluated 5 different survey designs for estimating zebra mussel density (2 designs in 2017 and 3 designs in 2018), employing methods that utilize counts by two divers to estimate the probability of detecting mussels in the surveyed area. We also compared survey designs in terms of their density estimates, associated measures of uncertainty, and sampling efficiencies (time required to complete a survey), using data collected in 3 lakes of varying density and using a simulation study and analytical framework informed by our data. In 2017 in Lake Burgan, we estimated that a diver could detect between 5% and 41% of the mussels present in the surveyed area, depending on the specific diver and on whether the lake bottom was vegetated, with vegetation having the larger effect on detection. Accounting for low detectability of zebra mussels led to an estimate of density over three times higher than the observed density. Thus, for every zebra mussel detected by our divers, approximately two were missed. Using the data collected in 2018 and further simulation and analytical work, we found that double-observer survey designs that allow for imperfect detection are optimal when surveying lakes at low density, whereas quadrat counts that assume perfect detection are optimal at higher densities. We developed a training video, data collection worksheets, and an analysis tutorial so that others may implement our proposed survey designs in newly infested lakes. These tools benefit MNn's by providing better ways to monitor lakes infested with zebra mussels and to evaluate the effects of treatment options on zebra mussel density.

PROJECT RESULTS USE AND DISSEMINATION

We have developed several resources to facilitate uptake of our survey methods, including a website describing the project (https://zebramusselsurveys.netlify.com/), an instructional video demonstrating the survey methods (https://www.youtube.com/watch?v=E3ui8SVeBC0&feature=youtube), data sheets and google forms for data entry (https://zebramusselsurveys.netlify.com/forms), and an analysis vignette or tutorial using open-source software to analyze data collected from our survey designs (https://zebramusselsurveys.netlify.com/tutorial).

We have submitted a paper to Freshwater Science describing the survey methods we used in our first field season, along with estimates of density in Lake Burgan in 2017; we received a favorable review, and it has been forwarded to the editor for final consideration. We are currently working on an additional manuscript comparing the different survey methods in terms of their sampling efficiency (time required to complete a survey) and the resulting density estimates and associated measures of uncertainty using data collected in 3 lakes of varying density and using a simulation study and analytical framework informed by our data.

We have presented our research results via oral and poster presentations at professional conferences (Upper Midwest Invasive Species Conference, Hawaii Conservation Conference), MAISRC Research & Management Showcase events (oral presentations and a "hands on" demonstration of our survey designs), and a MAISRC outreach event sponsored by the Pelican River Watershed District. In the fall of 2019, we plan to offer a MAISRC-sponsored webinar to discuss our work, allowing us to reach a broad audience of scientists and managers interested in zebra mussel monitoring and control efforts.

Subproject 14 Completed: 06/30/2019 **FINAL REPORT**

Estimating densities of zebra mussels *(Dreissena polymorpha)* in early invasions using distance sampling

---

Sub-Project 16: Sustaining walleye populations: assessing impacts of AIS - $198,700 TF

Dr. Gretchen Hansen
University of MN
2003 Upper Buford Circle
135 Skok Hall
St. Paul, MN 55108
Phone: (651) 248-4228
Email: ghansen@umn.edu
Web: https://gretchenhansen.squarespace.com/

OVERALL PROJECT OUTCOME AND RESULTS

MN lakes experience ecosystem-level changes following the introduction of aquatic invasive species (AIS), specifically zebra mussels and spiny water fleas. However, the effects of these AIS on fish are poorly understood and vary among lakes. We evaluated the impacts of zebra mussels and spiny water fleas on walleye and yellow perch in MN's nine largest walleye lakes. We compared age-0 walleye and yellow perch growth over 35 years, including pre- and post-invasion. Age-0 walleye were >10% smaller at the end of summer following invasion by either AIS. Age-0 yellow perch growth decreased following zebra mussel invasion, although this effect was not statistically significant. Smaller length at the end of the growing season was associated with decreased survival to later life stages for walleye in 7 of the 9 study lakes.

We used stable isotope analyses to understand which habitats and food resources support walleye and other fish and to assess their position in the food web in each lake. We documented a high degree of variability in the resources supporting all life stages of walleye. In general, juvenile walleye relied on offshore prey resources in invaded lakes. Combined with reduced growth rates, these results suggest that as zooplankton food resources decline following invasion, young walleye are not sufficiently accessing alternative prey resources to maintain pre-invasion growth rates. Variability in walleye diets among lakes may reflect differences in lake productivity or morphology, not necessarily the presence of AIS.

Our results demonstrate that zebra mussels and spiny water flea influence the growth rates of age-0 walleye and that a wide range of food resources and habitats support walleye in these lakes. Declines in growth rates of young walleye are an early signal of potential negative effects on walleye. This information can guide managers on the most effective and sustainable walleye harvest and stocking strategies in invaded lakes.

PROJECT RESULTS USE AND DISSEMINATION

- A manuscript documenting the results of our historical growth analysis has been submitted to the peer-reviewed journal Biological Invasions (submitted draft attached).
- We have delivered several presentations at scientific conferences, meetings with managers, and to the public:
- Our work has been covered in the popular press and University media:

- DNR Launches high-tech study of food webs in MN's largest walleye lakes. Tony Kennedy, Star Tribune. 19 August 2017 - http://www.startribune.com/dnr-launches-high-tech-study-of-food-webs-in-MN-s-largest-walleye-lakes/441088893/
- MN scientists dive deep to learn why walleye are stressed. Dan Gunderson, MN Public Radio. 18 July 2017 - https://www.mprnews.org/story/2017/07/18/scientists-digging-deeper-to-understand-factors-affecting-walleye
- Are lake invaders affecting walleye? June Breneman, NRRI news. 27 July 2017 - https://www.nrri.umn.edu/natural-resources-research-institute/news/ais-walleye

- We worked with MAISRC communications staff to develop a project fact sheet (Attached), which we distributed to interested citizens and to DNR offices.
- We have maintained an active social media presence (on Twitter) describing our ongoing research. The MNDNR and NRRI public information staff are in contact with the MAISRC communications coordinator to facilitate posting of information to social media posts of all three organizations.
- We worked with MAISRC staff to develop a video describing our work, viewable here: https://www.maisrc.umn.edu/news/walleye-video

Subproject 16 Completed: 06/30/2019 **FINAL REPORT**

Aquatic Invasive Species Fact Sheet

Sub-Project 17: Building scientific and management capacity to respond to invasive Phragmites in MN - $283, TF

Daniel Larkin
U of M - MN Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 625-6350
Email: djlarkin@umn.edu
Web: http://larkinlab.cfans.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

MnPhrag is an early detection and response effort targeting invasive Phragmites australis (common reed) (www.mnphrag.org), with the goal of supporting landscape-scale, strategic management throughout MN. We mapped the distribution of invasive Phragmites, investigated its spread potential, and developed strategies for coordinated response in collaboration with agency staff and other resource managers. We engaged professionals and citizen scientists in reporting suspected populations; conducted intensive search efforts in under-sampled regions; and revisited unverified reports from a web-based invasive species reporting system. Over 70 active observers helped us identify 435 invasive Phragmites populations statewide, and we showed that non-experts can reliably distinguish invasive from native Phragmites using an identification guide we developed (www.maisrc.umn.edu/identifying-phragmites). The value of this "crowdsourcing" approach to surveillance is reflected in most invasive stands we identified being small populations (90% are <0.25 acres), for which effective control is much more feasible. Invasive Phragmites is producing viable seed in MN, which increases spread risk;

however, the extent of seed production varies across populations, and there is still time to prevent further spread through sound, sustained control efforts. We are working closely with diverse stakeholders to support coordinated response efforts. Our work has also brought state agencies together to address crosscutting issues related to invasive Phragmites' regulatory status, including its use in some wastewater treatment facilities in "reed beds" for removing water from biosolids. We recently published an action plan outlining how Phragmites spread could be stopped and reversed in MN; this assessment includes management recommendations, cost estimates, and region-specific response guidance (www.maisrc.umn.edu/reversing-spread). Our findings reveal a window of opportunity to slow and reverse spread of invasive Phragmites, which would benefit MNns by protecting vital natural resources. This approach to statewide surveillance, and framework for a coordinated, landscape-scale response, are strategies that could be applied to other invasive species issues in MN.

PROJECT RESULTS USE AND DISSEMINATION

Information from this project has been disseminated through 19 invited talks, 6 contributed presentations, 1 webinar, 1 radio interview, and reports and resources published on our website (www.mnphrag.org). Our Phragmites Identification Guide and the report "An assessment to support strategic, coordinated response to invasive Phragmites australis in MN" are included as attachments. Project findings are being used by the MN Noxious Weed Advisory Committee, the MN Department of Natural Resources, the MN Department of Agriculture, and the MN Pollution Control Agency to assess risk of Phragmites invasion in MN and review relevant regulations, permitting, and policy.

Subproject 17 Completed: 06/30/2019 **FINAL REPORT**

An assessment to support strategic, coordinated response to invasive *Phragmites australis* in MN
A Guide to Identifying Native and Non-native Phragmites australis

---

Sub-Project 18: Eurasian and hybrid watermilfoil genotype distribution in MN - $221,375 TF

Raymond M Newman
U of M - MN Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 625-5704
Email: RNewman@umn.edu
Web: https://fwcb.cfans.umn.edu/personnel/raymond-newman

OVERALL PROJECT OUTCOME AND RESULTS

Eurasian watermilfoil (Myriophyllum spicatum) is one of the most problematic invasive aquatic plants in MN. It can hybridize with the native northern watermilfoil (M. sibiricum) and reproduce sexually. Previous studies show that some genotypes of hybrid are resistant to specific herbicides and some may be more invasive. We determined the distribution of hybrid, Eurasian, and northern watermilfoil in MN and assessed factors related to this distribution. We also assessed genetic variation (diversity) and distribution of specific genotypes and began an assessment of the response of watermilfoil and genotypes to management with herbicides. We sampled 64 lakes across the state stratified by county, size, and duration of infestation and collected milfoil from random points. The DNA from the milfoil samples was analyzed to determine taxon (Eurasian, northern or hybrid) and specific genotypes.

We found Eurasian in 43 lakes, hybrid in 28 lakes, and northern in 23 lakes. Hybrid was much more common in the metro, whereas Eurasian was broadly distributed. Northern watermilfoil was the most diverse with 84 genotypes, none shared across lakes. In contrast, we found one widespread genotype of Eurasian and six others found in indivdual lakes. Hybrid was intermediate in diversity with 53 genotypes; most lakes had only 1 unique genotype but 40% had multiple hybrid genotypes. Several genotypes were found in multiple lakes indicating clonal spread. The high diversity of hybrid watermilfoil indicates there is much potential for selection of problematic genotypes that are resistant to herbicides or that are competitively superior. There are numerous hybrid genotypes that could become problematic, but few have been widely distributed. We have not yet identified any clearly problematic genotypes in MN but lakes with unexplained treatment failures, and populations with high diversity should be assessed. We will implement a strategy to identify and test problematic genotypes in Phase II of this project – MAISRC Subproject 18.2: Genetics to improve hybrid and Eurasian watermilfoil management.

PROJECT RESULTS USE AND DISSEMINATION

We disseminated our results with presentations at the MAISRC Research & Management Showcase, several regional meetings and the national Aquatic Plant Management Society. We met with DNR Specialists, lake managers, consultants and other stakeholders twice to present results and to seek input on further work. In conjunction with MAISRC staff, we developed a Google Map indicating the locations we sampled and found Eurasian, hybrid and northern watermilfoil (https://www.maisrc.umn.edu/hybrid-distribution). This map will be updated as we get new information. We also generated a preliminary report in March 2019 and a final report detailing the background, methods, results and conclusions for distribution to managers and stakeholders and posting on the MAISRC website. The DNR and managers are starting to take this information into account when planning control activities.

Subproject 18 Completed: 06/30/2019 **FINAL REPORT**

Eurasian and hybrid watermilfoil genotype distribution in MN

Sub-Project 19: Decision-making tool for optimal management of AIS - $299,363 TF

Dr. Nicholas Phelps
U of M - MN Aquatic Invasive Species Research Center
135 Skok Hall
2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 624-7450
Email: phelp083@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

Understanding the patterns of historic AIS invasion can provide the framework for forecasting future invasions. To that end, we used a big data approach to combine hydrologic connectivity and boat movement to create a multiplex metacommunity model for both zebra mussel and Eurasian watermilfoil. We found that the hydrological corridors are important pathways of spread, even more so that previous research has suggested. While overland dispersal of AIS via boater movement is still a significant factor, additional management strategies should be developed to include intervention of hydrological pathways.

Using connectivity networks of boater movement, we developed county-based AIS management optimization models that prioritize inspection locations that will intercept the highest number of 'risky boats' (e.g. moving from infested to uninfested lakes). We piloted the models in Crow Wing, Ramsey, and Stearns Counties and had a very productive collaboration with county managers and citizen advisory boards during the development and evaluation for each. Ultimately, the application of this approach was well received and helped inform allocation of their inspection hours at the county level (for example: https://www.crowwing.us/1004/Aquatic-Invasive-Species-AIS).

Dissemination and usability of the models was a priority of this project. We created online tools to 1) visualize the spread risk for zebra mussels and Eurasian watermilfoil based on model predictions made in Activity 1, and 2) visualize and modify the decision optimization model at the county level based on management thresholds or funding availability. These tools and more detailed descriptions of the project has been disseminated through in-person stakeholder meetings and presentations to diverse audiences, including managers, researchers and the public.

PROJECT RESULTS USE AND DISSEMINATION

Efforts were made throughout the project to engage end-users, share findings and make deliverables broadly available. We used a combination of formal and informal dissemination strategies for this project given the direct application to AIS managers and broad interest among other stakeholders. We held in-person meetings with County representatives and citizen advisor boards from Crow Wing, Ramsey and Stearns Counties to present results and update our models according to their input. These meetings were highly valuable to the project team and the outcomes of the project. In addition, we provided scientific and/or outreach presentations at the International Conference on Aquatic Invasive Species, the Aquatic Invaders Summit, the Cass County Watercraft Inspectors annual training, the annual AIS Roundtable, and MAISRC's Research and Management Showcase. Several publications are currently in late-stage drafts and will be submitted for peer-review in the coming months.

Subproject 19 Completed: 06/30/2019 **FINAL REPORT**

Sub-Project 21: Early detection of zebra mussels using multibeam sonar - $96,549 TF

Jessica Kozarek
St. Anthony Falls Laboratory, University of MN
2 SE 3rd Ave
Minneapolis, MN 55414
Phone: (612) 624-4679
Email: jkozarek@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

Zebra mussels pose a serious threat to MN lake and river ecosystems. However, monitoring zebra mussel populations is challenging because current methods for detecting and counting zebra mussel colonies rely on time consuming and expensive diving surveys, video imaging, or sampling of veligers (larvae), which limits the areas surveyed. Remote sensing techniques have been shown to quickly and efficiently gather spatially extensive information. Using this technology to detect zebra mussels would likely be much more efficient and more effective than traditional methods and could be used for early detection and warning in rivers, lakes and reservoirs and to track changes in zebra mussel density.

This project was the first phase of research designed to test the utility of a swath mapping system, multibeam sonar, for detecting the presence and abundance of invasive mussels. Laboratory experiments were conducted to test the feasibility of using multibeam sonar to distinguish zebra mussel containing substrates. Acoustic backscatter data were collected in a two meter deep tank over sand, gravel, and mixed substrate containing high and low densities of zebra mussels and with native mussels using combinations of different sonar settings (frequencies and pulse lengths). Machine-learning was used to differentiate the acoustic backscattering signatures in a data-driven substrate classifier approach. Using these methods, we were able to classify substrate by size and mussel density. Classification errors decreased with more sonar settings. For minimum errors of less than 20%, 8 sonar settings are required, and for minimum errors of 10% or less for all substrates, 12 sonar settings. Each sonar setting corresponds to a separate boat survey of an area with a multibeam sonar in the field. Therefore, the next phase of this research is to further develop and test multibeam sonar monitoring approaches in the field (MAISRC Subproject 21.2: Field validation of mulitbeam sonar zebra mussel detection).

PROJECT RESULTS USE AND DISSEMINATION

Research results from Phase I will be disseminated through a peer-reviewed publication (in preparation) and will inform Phase II field testing starting July 2019 (MAISRC Subproject 21.2: Field validation of mulitbeam sonar zebra mussel detection). During this one-year project, we participated in MAISRC Fellows meetings and presented our project to the public at the annual MAISRC Research & Management Showcase. The MN Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement Guidelines.

Subproject 21 Completed: 06/30/2019 **FINAL REPORT**

Sub-Project 26: Updating an invasive and native fish passage model for locks and dams - $90,827 TF

Anvar Gilmanov
University of MN
135 Skok Hall, 2003 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 626-2110
Email: agilmano@umn.edu
Web: https://www.maisrc.umn.edu/

OVERALL PROJECT OUTCOME AND RESULTS

The main purpose of the project was to develop an updated version of the Computational Fluid Dynamics Agent-Based (CFD-AB) fish passage model (Zielinski, et al., 2018) using the field/experimental data of fish passage through Lock and Dam #2. This updated CFD-AB model can better help stop invasive carps while allowing native fish to pass through Mississippi River locks and dams.

The subproject has been fulfilled for all the goals that were declared:

1. The computational code CFD-AB directed to enhance the simulation of swimming fish trying to pass through the navigation dams was updated/developed. The analysis of different fish passage index (FPI) showed that the values of FPI for the modified algorithm for a model channel (Gilmanov, et al., 2019, Water, under review) were greater than the FPI of the original algorithm

at about 16%. At this moment, no essential differences in fish passage index FPI for the original and modified model at LD2 and LD8 have been found. This effect can be explained by the special gate adjustments, which generate a rather high fluid flow prevented fish to pass through the dams. In other words, in case of blocking invasive species, the modified algorithm does not change the final results of FPI at LD2 and LD8. But the modified algorithm could play a positive role to help native fish to pass through the navigation dams in the case of changing gate adjustments leading to decrease flow velocity.

2. The modified algorithms now account for more realistic fish behavior, including placement of “attraction points”, such as resting zones characterized by low recirculating fluid flow. These parameters have been informed by the literature and unpublished field data collected on other projects.

3. Based on investigations of (Larson, et al., 2017, Kokotovich et al, 2017) it was reported that the “Invasive Front" is currently positioned in southern Iowa between Pool 14 and Pool 16. Therefore, the strategy of blocking bigheaded carp at Lock and Dams of MN should be reconsidered. It is well documented that the navigational dams have significantly altered the movement, spawning, feeding and other activities of native fish (Wilcox et al. 2004). Hence, managers should consider alternative strategies whereby navigation dams are adjusted to help native fish pass, instead of blocking invasive fish. This strategy could help with ecosystem restoration efforts and potentially improve natural resistance to invasion by bigheaded carps. To evaluate this strategy, simulations of walleye passing through LD2 have been executed. It has been shown that by changing gate adjustments, FPI=4% is for the original algorithm and FPI=12% for the modified algorithm. We have to note, that for current gate adjustments from USACE the FPI=0% for original and modified CFD-AB models. By utilizing active monitoring data of bigheaded carp managers could instantly change gate adjustments at LD2-LD8 by using our CFD-AB approach if the invasion front threatens MN.

PROJECT RESULTS USE AND DISSEMINATION

The results of the “MAISRC Subproject 26: Updating an invasive and native fish passage model for locks and dams” were/will be presented at the following events:

- MAISRC Research & Management Showcase (2018) with a poster presentation "A computational model provides a way to stop invasive carp at two key MN Lock and Dams." Discussions and conversation with different groups of people were very informative and helpful.
- 2018 Upper Midwest Invasive Species Conference that was held with a joint conference of North American Invasive Species Management Association on October 15-18, 2018 - Mayo Civic Center - Rochester, MN and made an oral presentation "Computational model of fish swimming through Mississippi River locks and dams demonstrates ways to stop carp."
- The paper (Gilmanov, et al., 2019, under review) with the description of development/modification of CFD-AB model was submitted to the “Water” (an Open Access Journal from MDPI).
- MAISRC Research & Management Showcase (2019) with a poster “Mississippi River Dams: blocking invasive fish, helping natives”.
- Additional paper "Spillway gate settings in Mississippi River navigation lock and dams can be used to help native fish upstream passage" is in process and will be submitted for review in October-November 2019.

- The computer code of fish swimming through the navigation dam LD2 will be prepared and put in the publicly accessible Data Repository and the University of MN (DRUM) system.

Subproject 26 completed: 06/30/2019 **FINAL REPORT**

Project Completed: 6/30/2019 **OVERALL FINAL REPORT**

- **Spreadsheet of all research projects completed between January 1, 2019 and December 31, 2020.**

Environment and Natural Resources Trust Fund (ENRTF)
Research Projects completed between January 1, 2019 and December 31, 2020
Full abstracts are included in Section III. Completed Research Projects

Year	Subd.	Title	Organization	First Name	Last Name	Funding Amount
2013	06a	An Aquatic Invasive Species Research Center	U of MN - MAISRC	Nicholas	Phelps	$ 8,700,000
2013	06a-02	AIS Research Center Sub-Project 02: Delaying the Spread of AIS: Monitoring the Abundance and Distribution of AIS Using New Molecular Tools so Techniques to Delay Their Spread can be Implemented	U of MN - MAISRC	Michael	Sadowsky	
2013	06a-03	AIS Research Center Sub-Project 03: Reducig and Controlling AIS: Developing Effective Tools to Attract and Locate Aggregations of	U of MN - MAISRC	Peter	Sorensen	
2013	06a-04	AIS Research Center Sub-Project 04: Reducing and Controlling AIS: Developing Effective Bio-Control Techniques to Control Common and/or Asian Carp	U of MN - MAISRC	Przemyslaw	Bajer	
2013	06a-07	AIS Research Center Sub-Project 07: Developing Eradication Tools: Exploring whether Native Pathogens can be used to Control AIS	U of MN - MAISRC	Nicholas	Phelps	
2013	06a-08	AIS Research Center Sub-Project 08: Implementing Findings: An Applied Ecologist - Extension Specialist Position and Program	U of MN - MAISRC	Daniel	Larkin	
2013	06a--09	AIS Research Center Sub-Project 09: Implementing Findings: ImplementinNew Tools for Zebra Mussel Control	U of MN - MAISRC	Michael	McCartney	
2013	06a-10	AIS Research Center Sub-Project 10: Implementing Findings: An Extension Educator or Outreach Position	U of MN - MAISRC	Daniel	Larkin	
2013	06a-12	AIS Research Center Sub-Project 12: Characterizing long-term spiny water flea ecosystem impacts using paleolimnology	U of MN - MAISRC	Donn	Branstrator	
2013	06a-14	AIS Research Center Sub-Project 14: Cost-effective Monitoring of Lakes Newly Infested with Zebra mussels	U of MN - MAISRC	John	Fieberg	
2013	06a-16	AIS Research Center Sub-Project 16: Sustaining Walleye Populations: Assessing Impacts of AIS	U of MN - MAISRC	Gretchen	Hansen	
2013	06a-17	AIS Research Center Sub-Project 17: Building Scientific and Management Capacity to Respond to Invasive Phragmites	U of MN - MAISRC	Daniel	Larkin	
2013	06a-18	AIS Research Center Sub-Project 18: Eurasian and Hybrid Watermilfoil Genotype Distribution in Minnesota	U of MN - MAISRC	Raymond	Newman	

Environment and Natural Resources Trust Fund (ENRTF)
Research Projects completed between January 1, 2019 and December 31, 2020
Full abstracts are included in Section III. Completed Research Projects

Year	Subd.	Title	Organization	First Name	Last Name	Funding Amount
2013	06a-19	AIS Research Center Sub-Project 19: Decision-Making Tool for Optimal Management of AIS	U of MN - MAISRC	Nicholas	Phelps	
2013	06a-21	AIS Research Center Sub-Project 21: Early Detection of Zebra Mussels Using Multibean Sonar	U of MN - MAISRC	Jessica	Kozarek	
2013	06a-26	AIS Research Center Sub-Project 26: Updating an invasive and native fish passage model for locks and dams	U of MN - MAISRC	Anvar	Gilmanov	
2014	06a	Enhancing Pollinator Landscapes	U of MN	Marla	Spivak	$ 864,000
2014	Sec 8 - 01	MITPPC #1: Novel Diagnostic Tools for Rapid and Early Detection of Oak Wilt	U of MN - MITTPC	Abdennour	Abbas	$ 271,911
2014	Sec 8 - 02	MITPPC #2: Early Detection, Forecasting and Management of Brown Marmorated Stinkbug (Halymorpha halys)	U of MN - MITTPC	William	Hutchison	$ 616,081
2014	Sec 8 - 03	MITPPC #3: Climate Change and Range Expansion of Invasive Plants	U of MN - MITTPC	David	Moeller	$ 206,335
2014	Sec 8 - 04	MITPPC #4: Cover It Up! Using Plants to Control Buckthorn	U of MN - MITTPC	Peter	Reich	$ 327,000
2015	03h	Reintroduction and Interpretation of Bison in Minnesota State Parks	MN DNR	Edward	Quinn	$ 600,000
2015	03m	Turtle Population Dynamics in an Urban Lake	St. Thomas University	Jennifer	McGuire	$ 250,000
2015	04a	Understanding Water Scarcity, Threats, and Values to Improve Management	U of MN - Humphrey School of Public Affairs	Bonnie	Keeler	$ 234,000
2015	04g	Using Hydroacoustics to Monitor Sediment in Minnesota Rivers	US Geological Survey	Jeffrey	Ziegeweid	$ 455,000
2015	04h	Assessment of Irrigation Efficiencies in Benton County	Benton Soil and Water Conservation District	Gerry	Maciej	$ 431,000
2015	06b	Emerald Ash Borer Ecological and Hydrological Impacts – Phase II	U of MN	Anthony	D'Amato	$ 400,000
2015	06c	Biological Control of Canada Thistle	U of MN	Roger	Becker	$ 300,000

Environment and Natural Resources Trust Fund (ENRTF)
Research Projects completed between January 1, 2019 and December 31, 2020
Full abstracts are included in Section III. Completed Research Projects

Year	Subd.	Title	Organization	First Name	Last Name	Funding Amount
2015	06d	Preventing a New Disease of Pines in Minnesota	U of MN	Robert	Blanchette	$ 371,000
2015	07a	Renewable and Sustainable Fertilizers Produced Locally	U of MN	Alon	McCormick	$ 1,000,000
2016	03a	Data-Driven Pollinator Conservation Strategies	U of MN	Daniel	Cariveau	$ 520,000
2016	03c1	Prairie Butterfly Conservation, Research, and Breeding - Phase II	Minnesota Zoo	Erik	Runquist	$ 421,000
2016	03c2	Prairie Butterfly Conservation, Research, and Breeding - Phase II	MN DNR	Jessica	Petersen	$ 329,000
2016	03f	Assessment Tool for Understanding Vegetation Growth Impacts on Groundwater Recharge	U of MN	Gene-Hua (Crystal)	Ng	$ 212,000
2016	03j	Improving Brook Trout Stream Habitat through Beaver Management	Minnesota State University - Bemidji	Andrew	Hafs	$ 225,000
2016	03l	Restoration of Elk to Northeastern Minnesota	U of MN	James	Forester	$ 300,000
2016	03m	Game and Nongame Bird Pesticide Exposure	U of MN - Raptor Center	Julia	Ponder	$ 349,000
2016	03n	Evaluating Insecticide Exposure Risk for Grassland Wildlife on Public Lands	MN DNR	Nicole	Davros	$ 250,000
2016	03p	Evaluation of Tree Retention Guidelines Pertaining to Wildlife	U of MN - Duluth NRRI	Gerald	Niemi	$ 232,000
2016	03q	Determine Impacts on Wildlife From Emerald Ash Borer Infection of Black Ash Forests	U of MN - Duluth NRRI	Gerald	Niemi	$ 334,000
2016	04a	Tracking and Preventing Harmful Algal Blooms	Science Museum of Minnesota	Daniel	Engstrom	$ 500,000
2016	04b	Assessing the Increasing Harmful Algal Blooms in Minnesota Lakes	U of MN - St. Anthony Falls Laboratory	Miki	Hondzo	$ 270,000
2016	04d	Assessing Techniques for Eliminating Contaminants to Protect Native Fish and Mussels	St. Thomas University	Kristine	Wammer	$ 287,000

Environment and Natural Resources Trust Fund (ENRTF)
Research Projects completed between January 1, 2019 and December 31, 2020
Full abstracts are included in Section III. Completed Research Projects

Year	Subd.	Title	Organization	First Name	Last Name	Funding Amount
2016	04e	Assessing Neonicotinoid Insecticide Effects on Aquatic and Soil Communities	U of MN	William	Arnold	$ 400,000
2016	04f	Bacterial Assessment of Groundwater Supplies Used for Drinking Water	U of MN	Raymond	Hozalski	$ 299,000
2016	04h	Protection of State's Confined Drinking Water Aquifers - Phase II	US Geological Survey	Jared	Trost	$ 433,000
2016	04i	Assessment of Surface Water Quality With Satellite Sensors	U of MN	Jacques	Finlay	$ 345,000
2016	04j	Development of Innovative Sensor Technologies for Water Monitoring	U of MN	Tianhong	Cui	$ 509,000
2016	04k	Wastewater Treatment Process Improvements	U of MN	Timothy	LaPara	$ 398,000
2016	04l	Membrane-Based Process for Decentralized Drinking Water Production	U of MN	Santiago	Romero-Vargas Castrillón	$ 199,000
2016	04n	Understanding Impacts of Salt Usage on Minnesota Lakes, Rivers, and Groundwater	U of MN	John	Gulliver	$ 497,000
2016	04o	Microbes for Salt and Metal Removal	U of MN	Daniel	Bond	$ 596,000
2016	04p	Engineered Biofilter for Sulfate and Metal Removal from Mine Waters	U of MN	Sebastian	Behrens	$ 440,000
2016	04q	Developing Biosponge Technology for Removal of Nitrates from Minnesota Waters	U of MN	Lawrence	Wackett	$ 198,000
2016	04u	Assessing Effectiveness of Wetland Restorations for Improved Water Quality	U of MN	Jacques	Finlay	$ 420,000
2016	06b	Developing Membrane Filtration System to Treat Lake Superior Ballast Water	U of MN	Santiago	Romero-Vargas Castrillón	$ 151,000
2016	06d	Biological Control of White Nose Syndrome in Bats - Phase II	U of MN	Christine	Salomon	$ 452,000
2016	06f	Dutch Elm Disease Resistance - Phase II	U of MN	Robert	Blanchette	$ 200,000

Environment and Natural Resources Trust Fund (ENRTF)
Research Projects completed between January 1, 2019 and December 31, 2020
Full abstracts are included in Section III. Completed Research Projects

Year	Subd.	Title	Organization	First Name	Last Name	Funding Amount
2016	07b	Waste Heat Recovery with Efficient Thermoelectric Energy Generators	U of MN	Uwe	Kortshagen	$ 400,000
2016	07c	Hydrogen Fuel from Wind-Produced Renewable Ammonia	U of MN - WCROC	William	Northrop	$ 250,000
2016	07d	Utilization of Dairy Farm Wastewater for Sustainable Production	U of MN - WCROC	Bradley	Heins	$ 475,000
2016	08b	Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity	U of MN	Lauren	Sullivan	$ 556,000
2016	08c	Establishment of Permanent Habitat Strips Within Row Crops	Science Museum of Minnesota	Shawn	Schottler	$ 179,000
2016	08e	Controlling Reed Canary Grass to Regenerate Floodplain Forest	Minnesota State Office of National Audubon Society	Luis	Ramirez	$ 218,000
2017	04a	Assessment of Household Chemicals and Herbicides in Rivers and Lakes	U of MN	William	Arnold	$ 236,000
2017	04g	Identification of Chemicals of Emerging Concern in Minnesota Fish	Grand Portage Band of Lake Superior Chippewa	Seth	Moore	$ 400,000
2017	06d	Adapting Stream Barriers to Remove Common Carp	U of MN - MAISRC	Przemyslaw	Bajer	$ 301,000
2017	08b	Promoting Conservation Biocontrol of Beneficial Insects	U of MN	Vera	Krischik	$ 400,000
2018	03f	Develop a System to Assess Wildlife Health Threats in Minnesota	U of MN	Kimberly	VanderWaal	$ 280,000