

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)

Subd. 03 Water Resources

Solar Driven Destruction of Pesticides, Pharmaceuticals, Contaminants in Water - RESEARCH
Subd. 03a \$291,000 TF

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

\$291,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to quantify the solar-driven destruction of contaminants reacting with dissolved organic matter to optimize water treatment methods and guide reuse. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Pesticides, pharmaceuticals, and agricultural nutrients serve important functions in crop production and the treatment of disease. However, these chemicals become pollutants when discharged into surface waters through wastewater, storm water, and agricultural runoff. There are natural processes, though, that help break down and remove these pollutants from water. One such process is the role that sunlight interacting with dissolved organic matter naturally present in surface water from decaying plant materials and algae has in transforming these contaminants. Researchers at the University of Minnesota are using this appropriation to better understand the role this interaction between sunlight and dissolved organic matter has in affecting the fate of water pollutants in order to optimize water treatment methods and guide effective water reuse.

OVERALL PROJECT OUTCOME AND RESULTS

Urban stormwater, agricultural runoff, and municipal wastewater effluent transport pesticides, pharmaceuticals, and other trace organic compounds to aquatic systems. Once in the environment, these compounds are considered pollutants because they may have adverse ecological effects on non-target organisms. It may be possible to use or design wetland systems to take advantage of natural processes to maintain pollutant concentrations below harmful levels. Chemical reactions initiated by sunlight, also called photochemical reactions, are particularly important in degrading these pollutants. The organic matter (produced by the breakdown of plant material or from algae) dissolved in the water absorbs sunlight, and this process reactivates intermediates that breakdown pollutants.

In this work a method was developed to relate the amount of reactive intermediates produced to the source and composition of the organic matter. This allows prediction of how fast pollutants will be broken down by sunlight in surface waters impacted by stormwater runoff or wastewater effluents. Stormwater, wetland surface water, and municipal effluent samples were collected seasonally from Fall 2014 to Spring 2016 throughout the Minneapolis-St. Paul metro area and greater Minnesota. The efficiency of reactive intermediate formation was experimentally measured using chemical probes, and the composition of the organic matter was assessed using light absorbance

and fluorescence measurements and high-resolution mass spectrometry. Trends show that organic matter with low capacity to absorb light also has high efficiencies of reactive species formation. The relationship between reactive species formation efficiency and organic matter composition appears to be highly influenced by the content of the organic derived from plants. From this work, a model was developed to aid in the design of treatment wetlands to achieve pollutant removal by allowing an appropriate amount of time for sunlight exposure. In addition, an empirical multiple linear regression model using both chemical information about the organic matter and descriptors of the surrounding landscape was developed to aid in the prediction of reactive species formation in surface waters across regional scales. This will allow prediction of contaminant degradation via sunlight-driven reactions in a broad range of surface waters in Minnesota.

PROJECT RESULTS USE AND DISSEMINATION

This work has been presented at two sessions of the Environmental Chemistry Division of the American Chemical Society in March 2017 (both submitted with this report). This work has also been presented at poster sessions of the Minnesota Water Resources Conference (October 2016), the Conference on the Environment (November 2016), and the Year of Water Action Forum (March 2017; poster submitted with this report). One manuscript presenting the results of this work has been accepted for publication (July 2017; manuscript submitted with this report) and additional manuscripts are in preparation. Additional opportunities are being pursued to develop a pilot-scale treatment wetland to assess the accuracy and applicability of the models developed from this study.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Poster Presentation Graphic](#)

**Methods to Protect Beneficial Bacteria from Contaminants to Preserve Water Quality - RESEARCH
Subd. 03b \$279,000 TF**

Paige Novak

U of MN

122 Civil Engineering Bldg, 500 Pillsbury Dr SE
Minneapolis, MN 55455

Phone: (612) 626-9846

Email: novak010@umn.edu

Web: <http://www.cege.umn.edu/directory/faculty-directory/novak.html>

Appropriation Language

\$279,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to research how and why bacteria that provide ecological functions humans depend on for water quality are affected by exposure to certain man-made perfluorinated chemicals entering the wastewater treatment system in order to identify methods that can be implemented to protect those bacterial functions from being degraded. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Many types of bacteria perform critical ecological functions, such as cycling carbon and other nutrients, which enable life to exist. In fact, humans harness these types of bacteria in certain engineered systems, such as wastewater treatment plants and landfills, to provide various benefits such as protecting surface waters from excess nitrogen, decomposing solid waste, and treating wastewater. Unfortunately, the environments within these systems where the beneficial bacteria live are also environments that receive a complex array of synthetic chemicals that can negatively affect bacterial function, particularly when present in mixtures. One such class of chemicals that find their way into these systems is perfluorinated chemicals, which research has suggested can cause other co-contaminants to be more toxic to bacteria. Researchers at the University of Minnesota are using this appropriation to research how and why these beneficial bacteria are affected by exposure to perfluorinated

chemicals entering the wastewater treatment system in order to help develop and engineer methods to better protect and enhance the important ecological functions these bacteria provide.

OVERALL PROJECT OUTCOME AND RESULTS

We studied the effect of common pollutants, perfluorinated alkyl substances or perfluorinated substances (PFCs), on bacteria. PFCs are found throughout the environment from concentrations of 0.00001 mg/L in rivers to 10 mg/L at heavily polluted sites. Because humans rely on bacteria for nutrient cycling and waste degradation, it is important to understand whether PFCs affect bacteria. We studied PFCs with known health impacts, those containing 7-8 fully fluorinated carbons, along with shorter, 4- and 6-carbon "replacement" PFCs. We discovered that PFCs with 3-8 fully fluorinated carbons increased the permeability of bacterial membranes at high (mg/L) concentrations. We observed that these compounds deposited into model bacterial membranes and changed their fluidity at concentrations of 0.1 to 50 mg/L. This is significant because bacterial membranes form semi-permeable barriers; it is the semi-permeable nature of membranes that enable bacteria to communicate with one another and control metabolism. Increased membrane fluidity and permeability in bacteria induced by PFC exposure could have impacts on the bacterial functions that humans rely on.

Perhaps not surprisingly, we also discovered that PFCs with 3-8 fully fluorinated carbons altered the bacterial response to the external chemical signal used for bacteria-to-bacteria communication. This occurred at PFC concentrations of 0.01 to 50 mg/L. Finally, exposure to high (50 mg/L) concentrations of PFCs with 7-8 fully fluorinated carbons and PFC-containing aqueous film-forming foam changed microbial metabolism, decreasing the amount of carbon degraded to methane. The presence of a co-contaminant lessened this effect, likely as a result of the co-contaminant displacing the PFCs from the bacterial surface. This research indicates microbial metabolism is not likely to be affected by PFCs unless these compounds are present at high concentrations, such as at fire-fighting training sites. Nevertheless, the effects of PFCs on bacterial membranes and bacteria-to-bacteria communication at lower concentrations could cause unanticipated impacts.

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: 06/30/2017

[FINAL REPORT](#)

**Triclosan Impacts on Wastewater Treatment - RESEARCH
Subd. 03c \$380,000 TF**

Timothy LaPara

U of MN

500 Pillsbury Dr SE

Minneapolis, MN 55455

Phone: (612) 624-6028

Email: lapar001@umn.edu

Web: <http://www.cege.umn.edu/directory/faculty-directory/lapara.html>

Appropriation Language

\$380,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to assess the role of the commercially used antibacterial agent triclosan in creating antibiotic resistant bacteria during the municipal wastewater treatment process. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

As people use antibiotics and products containing antibacterial substances the bacteria that are resistant to the effects of these products survive and reproduce, thus creating a selection for antibiotic resistant bacteria. Many of these bacteria and the antibacterial substances ultimately make their way into the waste stream and are mixed together and concentrated at wastewater treatment plants, where they interact and can create further selection for organisms with antibiotic resistance to multiple antibacterial substances resulting in what are commonly known as "super bugs". If these antibiotic resistant organisms are not entirely removed during the wastewater treatment process, these organisms then are released into the environment where they can eventually affect humans and other species. One antimicrobial substance of particular concern is triclosan, which is present in numerous personal care products, because it has been shown to help select for organisms that show antibiotic resistance not just to triclosan but also to a multitude of other antibiotics. Researchers at the University of Minnesota are using this appropriation to improve understanding of the role of triclosan in selecting for antibiotic resistant bacteria during the municipal wastewater treatment process.

OVERALL PROJECT OUTCOME AND RESULTS

Laboratory-scale sequencing batch reactors were constructed and operated in triplicate at four different concentrations of triclosan (0 µg/L, 1 µg/L, 5 µg/L, and 15 µg/L). After six weeks of operation, biomass was harvested and used for 12 discrete sequencing batch reactors (SBRs) and operated them for a total of six weeks. Chemical analysis of the biomass for triclosan concentrations confirmed that the cultures were grown over the expected range of triclosan concentrations. Metagenomic DNA was extracted and purified from the biomass from these laboratory-scale cultures. Bacterial community composition was characterized by PCR of 16S rRNA genes followed by DNA sequencing using Illumina MiSeq. Results demonstrated that bacterial community composition shifted in a statistically significant fashion in response to higher triclosan doses. Direct DNA sequencing of metagenomic DNA demonstrated that only a few antibiotic resistance genes were overrepresented in the cultures with high triclosan concentrations compared to those with low triclosan concentrations. Specifically, *tet(R)* and *tet(A)* genes were overrepresented in the 5 µg/L triclosan treatment; *tet(R)*, *tet(A)*, *tet(X)*, *msrE*, and *sul1* were overrepresented in the 15 µg/L triclosan treatments. No statistical difference was observed for more than 2,100 other antibiotic resistance genes. Metagenomic DNA was also directly cloned and introduced into *E. coli* to select for functional antibiotic resistance genes. Each of the resulting clone libraries averaged 20,000 clones, the equivalent of more than 1300 bacterial genomes. All libraries were selected for genes conferring resistance to a panel of antibiotics. Sequence analysis indicated that the enzymes encoded by the resistance genes ranged from 57 to 100 percent identical to the closest matching proteins in the GenBank database. Many of these genes were found adjacent to each other on single DNA molecules. Two clones contained multiple resistance genes on integrons in arrangements that have not been previously reported in the literature.

PROJECT RESULTS USE AND DISSEMINATION

Results from this project have been presented at Microbe 2016, the annual meeting of the American Society for Microbiology and at the Functional Metagenomics 2016 conference in Inderøy, Norway. Manuscripts are currently being written for publication in the peer-reviewed archival literature.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Evaluation of Wastewater Nitrogen and Estrogen Treatment Options - RESEARCH

Subd. 03d \$500,000 TF

Paige Novak

U of MN

122 Civil Engineering Bldg, 500 Pillsbury Dr SE

Minneapolis, MN 55455

Phone: (612) 626-9846

Email: novak010@umn.edu

Web: <http://www.cege.umn.edu/directory/faculty-directory/novak.html>

Appropriation Language

\$500,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to examine the performance of new wastewater contaminant treatment options under Minnesota weather conditions in order to understand how to improve wastewater treatment of nitrogen and estrogenic compounds, decrease costs and energy use, and safeguard aquatic species. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Wastewater treatment plants discharge effluent that contains contaminants of emerging concern, such as estrogens. Estrogens have been shown to cause ecological effects such as fish feminization and fish population collapses. Presently the treatment and discharge of estrogens into the environment via wastewater treatment is not regulated. However, it has been found that the extent of estrogen discharge from wastewater treatment correlates with how and how well nitrogen, which currently is regulated and will likely be more so in the future, is removed during the treatment process. Thus more effective nitrogen removal processes have the potential to also ensure more effective removal of estrogens. Researchers at the University of Minnesota are using this appropriation to determine how different nitrogen removal processes perform under a variety of weather conditions with respect to how well they remove both nitrogen and estrogenic compounds in order to help improve wastewater treatment of nitrogen and estrogenic compounds.

OVERALL PROJECT OUTCOME AND RESULTS

Wastewater treatment plants (WWTPs) discharge effluent that contains contaminants of emerging concern (CECs), including estrogens. These estrogens have caused ecological damage, such as fish feminization, with unknown long-term consequences. The most important estrogen exiting WWTPs is a chemical called estrone. In this project we studied how different treatment systems performed with respect to estrone degradation and how temperature effected degradation. We also studied how fish vulnerability changed seasonally. Finally, we combined these laboratory efforts with models of fish population dynamics to extrapolate the results.

We determined that the technology used by a treatment plant is likely to have an impact on the estrogenicity of WWTP effluent, with some technologies performing very well and others failing to remove estrone. In addition, natural seasonal fluctuations in temperature and expected fluctuations in estrone concentration can cause negative changes in exposed fish. Mathematical models were used to expand this research to whole river systems and showed that the impacts of estrone on fish populations varied depending on the characteristics of the environment. Impacts were expected to be low in systems in which fish were limited by food and high in systems in which fish were limited by predators. Therefore, fish populations in Minnesota rivers are likely to vary in their response to wastewater estrone. The cost of various wastewater improvements were calculated, which could be compared to the value associated with recreational fishing.

Overall, this research showed that low energy treatment systems do exist that are capable of excellent estrone removal, which should be considered so that multiple ecological benefits can be reaped as treatment plants upgrade. Nevertheless, modeling results suggest that the impacts of estrone vary at the population scale based on river characteristics. Therefore, the impact of estrogens at the fishery scale should be evaluated for a given river of interest.

PROJECT RESULTS USE AND DISSEMINATION

Information from this project has been shared broadly and multiple peer-reviewed manuscripts have been published from this work and submitted to the LCCMR.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Individual Based Models for the fathead minnow *Pimephales promelas* and the walleye *Sander vitreus*: Report](#)
[Add-my-pet procedure for fathead minnow *Pimephales promelas* and the walleye *Sander vitreus*: Report](#)
[Thermal modulation of anthropogenic estrogen exposure on a freshwater fish at two life stages: Publication](#)
[Temperature modulates estrone degradation and biological effects of exposure in fathead minnows: Publication](#)
[Estrone biodegradation in laboratory-scale systems designed for total nitrogen removal from wastewater: Publication](#)

Antibiotics and Antibiotic Resistance Genes in Minnesota Lakes - RESEARCH

Subd. 03e \$300,000 TF

William Arnold

U of M

122 Civil Engineering Building

500 Pillsbury Dr SE

Minneapolis, MN 55455

Phone: (612) 625-8582

Email: arnol032@umn.edu

Web: www.cege.umn.edu/

Appropriation Language

\$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to quantify the relationship between antibiotics and antibiotic-resistant bacteria in Minnesota lakes to determine if improved wastewater treatment is necessary to protect human and aquatic health. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Through various means, human produced chemicals can make their way into surface waters where they can have adverse effects on the function of ecological communities. Of particular concern are antibiotics and other antimicrobial substances because they have the potential to create increased antibiotic resistance. While there is a background level of naturally occurring antibiotic resistance in the natural world, elevated or persistent levels caused by human activities have the potential to harm human, animal, and overall ecosystem health. Researchers at the University of Minnesota are using this appropriation to quantify and compare the levels within lakes of naturally occurring antibiotic compounds versus those resulting from human actions to delineate the role of each in creating antibiotic resistant bacteria and determine the extent to which improved wastewater treatment could contribute to controlling the amount of antibiotics and antibiotic resistant genes within the environment.

OVERALL PROJECT OUTCOME AND RESULTS

Antibiotics are substances that stop the growth of or kill bacteria. Animal agriculture and human medicine are the largest consumers of antibiotics worldwide. A fraction of the antibiotic administered is excreted in its original form through urine and/or feces. These residues reach aquatic environments through the discharge of wastewater effluent or drainage and surface runoff from agricultural fields to which manure has been applied. The presence of antibiotics in the environment are of concern, because these chemicals may select for and proliferate the occurrence of antibiotic resistance genes (ARGs). ARGs allow bacteria to survive in the presence of an antibiotic. Heavy metals are also known to co-select for ARGs. The World Health Organization has identified antibiotic resistance as one of the major threats to global health. The increase in the prevalence of antibiotic resistant infections, coupled with the decrease in the development of new antibiotics, emphasize the need for new strategies to better understand antibiotic resistance.

The goal of the project is to quantify the current and historical levels of selected human and veterinary antibiotic compounds and genes that code for their resistance in lake sediments. Sediment cores collected for three anthropogenically-impacted Minnesota lakes (Lake Pepin, Duluth Harbor, and Lake Winona) and a control lake in Superior National Forest (Little Wilson Lake) were radiometrically dated. The twenty antibiotics included in this

study have a mixture of human and/or agricultural uses, some are known natural products, and they span several of the major classifications (sulfonamides, fluoroquinolones, tetracyclines, macrolides).

Sediment cores were successful at capturing the usage trends of ten antibiotics. The initial appearance of antibiotics in the sediment core generally agreed with the FDA approval date, which provided further confidence in the dating of the sediment cores and the ability of sediment cores to capture antibiotic usage trends. Ofloxacin, trimethoprim, sulfapyridine, and sulfamethazine were the only antibiotics to be detected in all three anthropogenically-impacted studied lakes with levels up to 91.7, 2.5, 13.1, and 5 ng g⁻¹, respectively. Human-use antibiotics were detected more frequently and at higher concentrations than antibiotics used for veterinary medicine. Also, the degree of antibiotic pollution appeared to be a function of treated wastewater impact. Lake Winona was the most heavily wastewater impacted lake in the study (approximately 63% of the inflow is treated wastewater effluent) and had the highest concentrations and greatest number of antibiotics detected. Treated municipal wastewater is likely the primary contributor to antibiotic pollution in the studied lakes.

The abundance of 48 antibiotic, metal, and antibiotic-associated resistance genes were quantified in the sediment cores with detected levels ranging from 103 to 108 gene copies per gram. Most ARGs included in this study, however, were not consistently quantifiable throughout the sediment cores. Similar concentrations of blaSHV, cadA, copA, int11, and mexB were measured amongst the sediment cores, but Lake Winona had higher levels of sul3 and tet(A) compared to the other lakes. ARGs levels did not appear to be a function of sediment core depth, and thus the measured levels are at or close to natural, indigenous background levels of the studied genes. Also, (unlike the antibiotics studied) ARG abundance did not appear to be a function of agricultural activity or degree of wastewater impact. Therefore, ARG abundance in the studied lakes is likely not influenced by antibiotic usage, but rather may be influenced by the presence of heavy metals that are known to co-select for ARGs.

PROJECT RESULTS USE AND DISSEMINATION

This project led to the production of chapters in the PhD dissertations of both Kyle Sandberg and Jill Kerrigan. Manuscripts will be submitted to the journals Science of the Total Environment and Environment Science and Technology Letters. Copies of manuscripts will be provided upon publication. The results of this work have been presented at least nine times at national and local conferences.

Project Completed: 06/30/2017

[FINAL REPORT](#)

**Impacts of Estrogen Exposure on Minnesota's Shallow Lake Wildlife - RESEARCH
Subd. 03f \$136,000 TF**

Kurt Illig

St. Thomas University
2115 Summit Ave, OWS 352
St. Paul, MN 55105

Phone: (651) 962-5273

Email: krillig@stthomas.edu

Web: <http://www.stthomas.edu/biology/faculty/kurt-r-illig.html>

Appropriation Language

\$136,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the University of St. Thomas to use biological samples already gathered from shallow lakes across Minnesota to determine the environmental estrogen exposure impacts on aquatic wildlife in shallow lakes for enhanced land and lake management. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Endocrine-disrupting contaminants such as environmental estrogens have been found and studied in large lakes and streams and shown to exist at concentrations that have adverse effects on wildlife. However, very little is known about the sources and effects of environmental estrogens in small, shallow lakes. Preliminary data suggests that these compounds are present in shallow lakes and have an effect on the survival and reproduction of wildlife. Researchers at the University of St. Thomas are using this appropriation to determine the extent to which aquatic wildlife in shallow lakes are being exposed to environmental estrogens, the land-use practices that correlate with exposure, and the amount of detrimental impact that exposure creates in order to enhance land and water management practices.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota's shallow lakes play an important role in the ecosystem by providing clean water, recharging groundwater stores, and sequestering chemical and soil runoff. These lakes also benefit citizens, both by providing opportunities for recreation (e.g., fishing, swimming) and by providing economic value as a site for various commercial ventures (e.g., summer camps, fisheries). Endocrine-disrupting contaminants, including environmental estrogens (EEs) are present in Minnesota's larger lakes and streams at concentrations which have adverse impacts on wildlife. However, very little is known about the sources and effects of EEs in small, shallow lakes. Importantly, the use of surrounding land and associated lake management practices may influence or exacerbate the effects of contaminants in these systems. By developing an assay that allows us to look at levels of EE exposure in the painted turtle, we have found that lakes across Minnesota have widely different chemical makeup, and that turtles in these lakes show different levels of exposure. By examining the brains of these animals, we have discovered that the size of certain structures related to reproduction is highly correlated with EE exposure. We are now examining the relationship between land-use practices in lake watersheds and the chemical makeup of these lakes.

PROJECT RESULTS USE AND DISSEMINATION

We presented work resulting from our efforts to develop a species-specific measure for VTG in painted turtles at the Midwest Regional Chapter meeting of the Society for Environmental Toxicology and Chemistry in April, 2017. We presented work that describes the relationship between VTG levels and brain structure at the North American Society for Environmental Toxicology and Chemistry annual meeting in November, 2017.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Watershed-Scale Monitoring of Long-Term Best Management Practice Effectiveness - RESEARCH

Subd. 03g \$900,000 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: dengstrom@smm.org
Web: <http://www.smm.org/scwrs/>

Appropriation Language

\$900,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix Watershed Research Station to evaluate the effectiveness of best management practices in reducing sediment and nutrient loads at watershed scales over long time periods. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Minnesota has widespread water quality impairments due to nonpoint-source pollution generated by agricultural, urban, and other human-altered lands. Mitigation of these impairments requires implementing best management practices (BMPs) that are designed to limit soil erosion and nutrient transport from lands to receiving waters. Long-term data sets of water quality and land-use history are needed to tease apart the many factors that affect water quality. In particular, data sets that span periods before and after BMP implementation are needed to determine BMP effectiveness. However, such data sets are lacking because water quality monitoring of our lakes and rivers did not begin until well after humans altered the landscape. To fill this data gap, Researchers at the Science Museum of Minnesota's St. Croix Watershed Research Station are using this appropriation to construct long-term historical water quality records through analysis of lake sediments in order to enable better determination of the effectiveness of BMPs on improving water quality.

OVERALL PROJECT OUTCOME AND RESULTS

Nonpoint-source pollution (NPS) by sediment and nutrients represents the greatest human impact to Minnesota surface waters, especially in agricultural regions, yet monitoring records are too short to demonstrate the magnitude of the impact or potential benefits of best-management practices (BMPs). To fill this knowledge gap, our project used sediment cores, land-use compilations, and watershed modeling to reconstruct the long-term record of how land use has contributed to sediment and nutrient pollution in our rivers and lakes, and whether BMPs have been effective in reducing this pollution. Watershed erosion gradually fills in lakes over time, and so lake-sediment accumulation provides a record of watershed-scale erosion rates and changes.

We first re-analyzed statewide data from 142 lakes in our extensive lake-core archive. We then selected 14 lakes from the southern half of Minnesota for intensive analysis, collected 57 sediment cores from these lakes, and analyzed over 4,000 samples from these cores to determine the accumulation rates of sediment and phosphorus over the past 150 years. Radioisotope analysis determined the sediment age and source, whether from fields or stream channels. The results confirm that sediment erosion increased from the time of settlement in concert with increased cropland and the subsequent replacement of hay and small grains by corn and soybean row crops. In our intensive study lakes, sediment accumulation increased 2-10 (average 6) times over natural (pre-settlement) rates, and phosphorus accumulation increased 2-8 (average 5) times over natural rates. Radioisotopic fingerprinting indicated most of the lake sediment originated from fields, which is in contrast to our larger rivers such as the Minnesota, where bluffs and stream banks are the major erosion sources. Watershed modeling linked soil erosion to lake-sediment accumulation and confirmed that while BMPs produce beneficial results, they are overwhelmed by increases in row-crop acreage. We conclude that Minnesota needs to look beyond conventional BMPs towards putting more perennials in our croplands to achieve substantial water-quality improvement.

PROJECT RESULTS USE AND DISSEMINATION

Presentations have been given to the following groups in the Twin Cities and in out-state Minnesota: Clean Water Council; "Moving the Needle" taskforce to follow up on Governor Dayton's Water Summit; Working Lands group, as organized by BWSR; Greater Blue Earth River Basin Alliance; Chippewa Watershed "10% Project"; Isaac Walton League (joint meeting for southern Minnesota chapters); Lake Pepin Legacy Alliance; Friends of the Mississippi River; Upper Mississippi River Conservation Alliance (in partnership with the U.S. Fish and Wildlife Service); Friends of the Star Prairie Land Preservation Trust; Great Lakes Protection Commission (national meeting). A special session is planned for this year's Minnesota Water Conference on "The Need for and Potential of Creating Markets for BMPs" where project results will be discussed. Finally, a series of fact sheets will summarize the main components of the project for water-resource managers and an educated lay audience.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Protection of State's Confined Drinking Water Aquifers - RESEARCH

Subd. 03h \$394,000 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

\$394,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the United States Geological Survey to test methods of defining properties of confined drinking water aquifers in order to improve water management. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

The groundwater contained in confined glacial aquifers provides clean drinking water to many Minnesota residents. An important factor affecting the long-term sustainability of these aquifers is how water infiltrates through clayey deposits of overlying glacial till, which act as barriers to contaminants but also limit water flow and aquifer recharge. Very little is actually known about the properties and infiltration of water through till, which hinders the ability to accurately define the sustainability of these aquifers. The United States Geological Survey is using this appropriation to test methods for assessing and defining the hydrologic properties of glacial till in order to understand the role it plays in the long-term sustainability of groundwater.

OVERALL PROJECT OUTCOME AND RESULTS

Confined (or buried) aquifers overlain by till confining units provide drinking water to thousands of Minnesota residents. These till confining units are typically conceptualized as having very low potential for transmitting water. Thus, buried aquifers are thought to be less susceptible to surface contamination, but may recharge very slowly and may be prone to unsustainable groundwater withdrawals. This study was completed to give insight to the susceptibility and sustainability of the groundwater resources being withdrawn from confined aquifer systems in Minnesota. A combination of hydrologic field measurements, geochemical analyses, and modeling techniques were used to quantify the variability of hydrologic properties and flux of water through till confining units to buried aquifers at two representative sites in Minnesota. Glacial deposits of the Des Moines Lobe were characterized in Litchfield, Minnesota and glacial deposits of the Superior Lobe were characterized in Cromwell, Minnesota. A conceptual understanding emerges from the field measurements at the two sites that till "layers" in the glacial deposits of the Des Moines and Superior Lobes in Minnesota are not really continuous layers, but rather a complex series of sediment mixtures with differing abilities to transmit water. The hydrologic field measurements and geochemical analysis demonstrated large variations in till confining unit properties over relatively small vertical and horizontal distances, underscoring the challenges of assessing the susceptibility and sustainability of groundwater resources in confined aquifer systems.

Many waters in Minnesota are under threat of nutrient contamination from anthropogenic activities such as row-crop agriculture. This study provided some evidence that till confining units may be effective at reducing the susceptibility of buried aquifers to nitrate contamination, but may be a source of phosphorus. Data from Litchfield show that chloride is present in elevated concentrations where nitrate is not, despite abundant agriculture in the surrounding area. This suggests that denitrification may be occurring within the till; previous studies have demonstrated denitrification in Des Moines lobe tills (Simpkins and Parkin, 1993; Parkin and Simpkins, 1995). Phosphorus, though present at depth, particularly in Cromwell, is likely geologic rather than anthropogenic in origin.

The conceptual modeling demonstrates the importance of having accurate information, about the hydrogeologic setting (particularly about the vertical hydraulic conductivity of overlying till, the areal extent of the buried aquifer, and the lateral connectivity of the buried aquifer to other aquifers) when evaluating the sustainability of pumping water from confined aquifer systems. Over long periods of time, pumping-induced hydraulic gradients can be established in buried aquifer systems and, even in low hydraulic conductivity tills, these gradients could induce

flow that affects surface-water resources. The source of water entering a buried aquifer that is being pumped can be highly variable, depending on the overlying till vertical hydraulic conductivities and the lateral connectivity of buried aquifer to adjacent till and aquifers. A sensitivity analysis demonstrated that the simulation of the source of water to wells is most sensitive to the vertical hydraulic conductivity of the overlying till, the areal extent of the aquifer, and the connectivity of the horizontal hydraulic conductivity of geologic materials adjacent to the aquifer.

PROJECT RESULTS USE AND DISSEMINATION

As the result of this project, 4 publications were produced and 1 in preparation. A total of 9 presentations were given to audiences; 5 presentations at professional meetings and 4 public presentations.

Project Completed: 06/30/2017

FINAL REPORT

Minnesota Geological Survey Report

MDH Cromwell Well Aquifer Test

MDH Litchfield Well Aquifer Test

Watershed Water Budgets for Managing Minnesota's Groundwater - RESEARCH

Subd. 03i \$129,000 TF

Erik A. Smith

US Geological Survey

2280 Woodale Dr

Mounds View, MN 55112

Phone: (612) 419-4777

Email: easmith@usgs.gov

Web: <http://mn.water.usgs.gov/index.html>

Appropriation Language

\$129,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the United States Geological Survey to create a pilot study to calculate complete watershed water budgets for two counties in Minnesota for enhanced groundwater management. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Effective groundwater management requires accurate knowledge about the water budget, which is the amount of water stored within the system in aquifers and the amount of water flowing through the overall hydrologic system including water flowing at the surface, water flowing from above ground down into aquifers, and water flowing between aquifers below the surface. While groundwater storage can be generally well understood and there is good knowledge about surface water flow, there is not usually a strong understanding about the water flowing down from the surface to aquifers and below the surface between different aquifers. The United States Geological Survey is using this appropriation to pilot a method intended to better calculate the groundwater flow component of the hydrologic system in order to provide information that will improve knowledge about water sustainability and the interaction between surface and ground water. The method will be piloted in watersheds in St. Louis and Goodhue counties.

OVERALL PROJECT OUTCOME AND RESULTS

A new visual mapping technique that illustrates the relative and cumulative streamflow contributions from across a large watershed was developed for two pilot areas in Minnesota: Cannon River and St. Louis River. Both areas were selected because of mining-related activities. For the Cannon River, for the surficial sand mining, and for the St. Louis River, for the ongoing iron ore mining of the Mesabi Iron Range. Each large watershed (Cannon, St. Louis) was sub-divided into a series of much smaller sub-watersheds (Cannon: 153; St. Louis: 353). For each sub-watershed, the estimated groundwater (as baseflow) and surface runoff fluxes flowing into all surface-water

features was summed under different typical conditions, such as drought or flood conditions. Downstream sub-watersheds aggregate upstream surface-water flows in addition to baseflow and surface runoff directly from the sub-watershed. These maps, termed as streamflow distribution maps, can help illustrate sub-watersheds that are vulnerable due to either groundwater or surface-water appropriations, particularly under drought conditions. For each pilot watershed, a series of the streamflow distribution maps were developed at selected flow regimes: extreme drought conditions, drought conditions, an average condition, and a flood condition. Each pilot watershed is displayed as a single map sheet with the four flow regimes as separate panels for ease of comparison. The selected streamflow distribution maps illustrate streamflow contributions from different parts of the watershed for typical conditions, not necessarily the contribution for any particular time. These maps will provide a tool for State cooperators, such as the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency, for proactive water management and water-use sustainability. Furthermore, by highlighting the sub-watersheds in terms of surface-water flows, the streamflows can be evaluated in the context of meeting specific ecological flows under different flow regimes and potentially assist with decisions regarding groundwater and surface-water appropriations.

PROJECT RESULTS USE AND DISSEMINATION

The new visual mapping technique will be summarized in a U.S. Geological Survey Scientific Investigations Map (SIM). The SIM series includes map sheets and an accompanying report to discuss the methodology for creating the map products. In the case of this study, the SIM will include the following: (1) separate map sheets for each watershed (Cannon River, St. Louis River) that includes four panels of selected flow regimes: extreme drought, drought, mean flow, and flood; (2) the accompanying report with included tables and figures that support the map construction; (3) three separate model archives related to the mapping work. The web locations for the Scientific Investigations Map and model archives will be included with the final report, expected to be completed by November 2017. With this final workplan update/progress report, a complete draft of the SIM and the accompanying map sheets has been included. By the requirement of U.S. Geological Survey guidelines, all materials used in the construction of these maps will be made available through public webpage (<https://www.usgs.gov/>) upon release of the final SIM report.

The U.S. Geological Survey also organized two phone calls during the project timeline to interface with key partners from the Minnesota Department of Natural Resources (MNDNR) and the Minnesota Pollution Control Agency (MPCA). These meetings were meant to ensure that the mapping products produced from the project would meet their needs, and the USGS project team did adapt some of the final products to make the maps more useful. Keen interest was shown in the final products, and upon release of the final Scientific Investigations Map, the lead project managers (Erik Smith and Chris Sanocki) will be meeting again with key MNDNR and MPCA to develop next steps for other watersheds in the State.

Project Completed: 06/30/2017

FINAL REPORT

[Streamflow Distribution Maps Report](#)

[Cannon River drainage basin Soil-Water-Balance model data set](#)

[St. Louis River drainage basin Soil-Water-Balance model data set](#)

Identifying Causes of Exceptionally High Mercury in Fish - RESEARCH

Subd. 03j \$743,000 TF

Bruce Monson

Minnesota Pollution Control Agency

520 Lafayette Rd N

St. Paul, MN 55155

Phone: (651) 757-2579

Email: bruce.monson@state.mn.us

Web: <http://www.pca.state.mn.us>

Appropriation Language

\$743,000 the second year is from the trust fund to the commissioner of the Pollution Control Agency to quantify the probable causes of high mercury levels in fish within the Roseau River and two tributaries of the Red River of the North by comparing mercury movements within watersheds to understand the drivers of mercury biomagnifications in the food web of rivers with similarly high mercury levels and to guide further mercury reduction initiatives. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Most mercury in Minnesota waters is deposited from the atmosphere as a byproduct of burning coal and other compounds. Once in the environment, mercury can convert to a form called methylmercury where it bioaccumulates up the food chain from microscopic plants and animals to fish and then to humans and wildlife that consume the fish. The first step in solving the problem of mercury in fish is reducing the sources of mercury entering waters. Significant efforts are underway to reduce the amount of mercury released from human sources such as smokestacks and wastewater discharge, which will address the majority of the mercury entering the environment. However, there are a percentage of watersheds where mercury appears to have enhanced concentrations due to factors that are particular to the ecology of a watershed and not mainly driven by the amount of mercury entering the watershed. The Minnesota Pollution Control Agency is using this appropriation to better understand the probable causes of high mercury levels in fish in watersheds where atmospheric deposition alone does not account for the high mercury levels in order to determine what additional measures beyond source reduction can be taken to reduce mercury levels in those watersheds.

OVERALL PROJECT OUTCOME AND RESULTS

This study investigated probable causes of higher mercury levels in fish in certain mercury-impaired Minnesota rivers. We hypothesized that these high fish-mercury concentrations are caused by increased efficiency of mercury transmission to fish. To evaluate this, we measured mercury flow through the watershed, conversion of mercury to methylmercury, and accumulation of methylmercury in the riverine food web. The first two processes determine mercury availability to the food web, while the structure of the food web also determines mercury in fish. The project focused on the Roseau River, in the Red River Basin, with comparison measurements in six other rivers. Also in the Red River Basin, Thief River was chosen for its similarity and proximity and the Mustinka River because of its relatively low fish-mercury levels. The other rivers had high mercury levels in fish, similar to Roseau, but differed in watershed land cover and water chemistry. Data collection for this project is complete, but data analysis will continue.

Mustinka had the lowest methylmercury levels, and the lowest rates of conversion of inorganic mercury to methylmercury (methylation). Roseau and Thief Rivers had the highest methylmercury levels in water and biota, showing increasing methylmercury in the food web from upstream to downstream locations.

Although analysis of results will continue over the next several years, the preliminary results seem to indicate the dominant cause of high mercury in the food webs differ among the rivers and even within rivers. Organic carbon has a predominant role in transporting mercury, but inhibiting uptake by the food web. For instance, methylmercury levels in Vermilion River fish were similar to Roseau River, but levels in the water were much lower in Vermilion. Lake Vermilion appears to retain mercury before water flows to the Vermilion River; however, low organic carbon in the river allows more methylmercury available for uptake by the biota.

PROJECT RESULTS USE AND DISSEMINATION

Six presentations were completed by June 30, 2017, two poster presentations at the International Conference on Mercury as a Global Pollutant and four presentations at various scientific conferences. Three manuscripts are proposed for publication. When the data are compiled, analyzed, and reported, completed publications will be shared with LCCMR.

Project Completed: 06/30/2017

FINAL REPORT

Reducing Lake Quality Impairments through Citizen Action

Subd. 03k \$59,000 TF

Jen Kader

Freshwater Society

2424 Territorial Road Suite B

Saint Paul, MN 55114

Phone: (651) 313-5807

Email: jkader@freshwater.org

Web: <http://www.freshwater.org>

Appropriation Language

\$59,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Freshwater Society to train lake associations and other stakeholder groups to develop lake management plans and to implement science-based, citizen-led water quality improvement projects on impaired lakes in west central Minnesota. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Many lakes in Minnesota are classified as "impaired" for aquatic recreation and aquatic life as the result of nonpoint source pollution. These impairments can be addressed by the citizens that live by and have a vested interest in these water bodies, but there is often a lack of knowledge and resources to take effective action. The Freshwater Society is using this appropriation to train citizen groups in lake ecology and management in order to guide them in implementing water quality improvement projects for their local water bodies.

OVERALL PROJECT OUTCOME AND RESULTS

Since 2000, more than 400 lake associations have participated in the Healthy Lakes and Rivers Partnership (HLRP) program founded by Don Hickman of the Initiative Foundation and now run by Freshwater Society. HLRP is a program designed to help lake associations across the state identify and work towards the priorities they have for their water body, one county at a time. The round of HLRP funded through LCCMR allowed for collaboration with Otter Tail Soil and Water Conservation District, with specific attention focused on helping to align lake plans with County Water Plans so that local efforts could help to achieve county water quality goals.

In the last year and a half, four lake associations from Otter Tail County participated in a 2-day training covering the importance of lake planning, engaged in a Freshwater Society-led participatory planning process to define lake-specific and community-identified goals and strategies, drafted and finalized a Lake Management Plan specific to their lake (copies included in report), and began implementing those plans. These groups now have in their hands documents which detail specific stresses, threats, and opportunities for their lakes generated by RMB Laboratories, a clear indication of the shared vision of the community, and a 2-5 year action plan with steps they identified to help them realize these goals. Additionally, each group understands the resources that are out there to help them along the way, and has received \$5,000 of seed funds to get them started from West Central Initiative.

The four participatory planning sessions engaged a total of 184 lake residents from the county, and countless volunteer hours from the boards of the four lake associations to produce their own lake management plan for lakes representing hundreds of Minnesotans who have clear, community-identified goals and action plans to improve the health of their lakes.

PROJECT RESULTS USE AND DISSEMINATION

As a requirement for the final distribution of funds from West Central Initiative, all groups needed to send their final Lake Management Plans to East Otter Tail Soil and Water Conservation District. The groups are also planning to distribute the final versions to their member residents and local elected officials in one way or another. This may include a mailing of a portion of the plan, loading the final copy to the website, or providing a small supply to volunteer leaders within the association. Additionally, the Project Manager sent final plans to West Central Initiative so they could see how the funding was going to be used. Freshwater Society will also keep copies of the plan on file to be given to other interested persons upon request.

A blog post describing the project and outcomes will be published by Freshwater Society in coming months, and the project website will be updated to reflect the closure of the project and goals identified by the groups. Each lake association has been asked to check in with updates so that we may share how LCCMR funding has contributed to the success of community-led efforts to improve local water resources.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Lake Management Plan for Lake Six](#)

[Lake Management Plan for Big McDonald Lake](#)

[Lake Management Plan for Wall Lake](#)

[Lake Management Plan for Lake Lida](#)

Rainwater Reuse and Valuation Investigation

Subd. 03I \$300,000 TF

Scott Alexander

U of MN

310 Pillsbury Dr SE

Minneapolis, MN 55455

Phone: (612) 626-4164

Email: alexa017@umn.edu

Web: http://www.esci.umn.edu/orgs/geofluids/people_scott_alexander_home.html

Appropriation Language

\$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to design, install, and monitor a rainwater reuse system for use in evaporative chiller systems and identify other potential applications for rainwater reuse systems.

Project Overview

Rainfall runoff in urban areas contributes to localized flooding and washes contaminants and excess nutrients downstream affecting water quality. Systems to mitigate these problems can be challenging to implement in urban areas due to existing infrastructure and competing demands for land use. However, one option is to find alternative applications for the excess rainwater and use it replace the potable water that is currently being used for certain purposes. Researchers at the University of Minnesota are using this appropriation to evaluate alternative uses for captured rainwater. In particular the project will design and install a rainwater reuse system for integration into evaporative chiller systems, which are common in large buildings and currently account for a significant portion of summer water usage at these sites, and examine other potential reuses for rainwater, such as for toilet flushing and industrial processes.

OVERALL PROJECT OUTCOME AND RESULTS

This project evaluated rain water as a source for evaporative chillers and process water. Rain water has low dissolved solids and is better suited as process feed water than groundwater derived waters. The project

investigated the utility of capturing high purity water that would otherwise contribute to excessive runoff, localized flooding, and downstream nutrient and contaminant transport.

Harvested rain water was run through an evaporative concentrator simulating operation of commercial evaporative chiller systems. In contrast to conventional systems which required complete replacement of the system water after 3 to 4 cycles the rain water fed systems could run more than 30 cycles without replacement. After 30 cycles of evaporation the accumulated dissolved solids were still not precipitating minerals, especially calcite. In conventional systems mineral deposits must be prevented by the addition of chemicals and/or removed by acid washes in addition to frequent water replacement.

Based on the much smaller volume of feed water required with rain water, estimates of the seasonal chiller demand, roof area, rain fall rates, and storage volume can be made with a spreadsheet tool developed as part of this project. The required volume of water can be as little as 10% of the volume of ground water derived drinking water required for current systems. The costs of a roof water capture and treatment system is partially offset by savings on potable drinking water and to a larger extent by reducing the cost of other storm water retention and detention systems.

As part of a literature review other potential ways rain water can advantageously replace potable water were investigated ranging from toilet flushing, laundry, industrial processes, and anywhere the naturally dilute nature of rain water is an advantage. Traditional plumbing codes and definitions of gray water need to be updated to consider the relative cleanliness of roof run-off. In fact, many regions of the world where there is limited fresh water collect rain water as their sole drinking water source.

Unfortunately, a demonstration system designed for the UM campus could not be constructed within the project timelines, leaving a significant portion the grant funds unspent.

PROJECT RESULTS USE AND DISSEMINATION

Results were provided as a future addendum to the Minnesota Storm Water Manual in coordination with UM Extension Service. A journal article covering the potential for rain water reuse in commercial evaporative chiller systems is in review. We are working with local watershed districts, engineers, and architects to identify potential sites for rain water reuse systems in commercial settings. Presentations of this work have been made to the Mississippi Watershed Management Organization in Minneapolis and the Capital Region Watershed District in St. Paul.

Presently rain water is being used at the 17th Ave Residence Hall where roof runoff is stored for reuse in toilet flushing and at the Landcare Building where a cistern stores storm water for irrigation. Results from these systems show that rain water quality declines rapidly from pure rain water to roof runoff to street level runoff. Finding ways to capture the cleanest fractions of rain water for reuse this water instead of simply dumping it to the river is critical. Options for rain water reuse are particularly important where underground conditions limit infiltration of storm water and dense urban areas where there is no room for conventional storm water management systems. We have been in discussion with local storm water professionals and consulting firms about the use of rain water. Of particular interest are retail settings, like large shopping centers, that produce detrimental amounts of storm runoff but are resistant to giving up parking space for storm water management. These same retail areas use large evaporative chillers systems that consume significant ground water resources. In addition, rain water has great potential as feed for industrial process water. In particular, rain water can be easily polished through filtration and reverse osmosis to produce high purity water.

Project Completed: 06/30/2017 [Extended in M.L. 2016, Chapter 186]

[FINAL REPORT](#)

Measuring Hydrologic Benefits from Glacial Ridge habitat Restoration - RESEARCH
Subd. 03m \$168,000 TF

Myron Jesme

Red Lake Watershed District
100 Pennington Avenue South
Thief River Falls, MN 56701

Phone: (218) 681-5800

Email: jesme@wiktel.com

Web: <http://www.redlakewatershed.org/default.html>

Appropriation Language

\$168,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Red Lake Watershed District and the United States Geological Survey for completion of the analysis of flooding and water-quality benefits resulting from wetland and prairie restorations at Glacial Ridge National Wildlife Refuge.

Project Overview

Since 2000, a diverse group of partners has been collectively working in northwestern Minnesota on one of the largest prairie-wetland restorations in the world. Spanning 22,000 acres and adjacent to an additional 16,000 acres of public and private conservation land, the goal of the Glacial Ridge Project has been to demonstrate whether large-scale habitat restoration is a viable way to reduce flooding and improve water quality. Prior to beginning restoration efforts on the project, a comprehensive baseline hydrologic study of the area was completed by the U.S. Geological Survey (USGS). The Red Lake Watershed District and USGS are using this appropriation to complete a post restoration study that will quantify and evaluate the amount of flood reduction, water-quality improvement, and ecosystem-function change that has resulted from the wetland and prairie restoration efforts at Glacial Ridge. This information will be used to guide future restoration efforts throughout the state and beyond.

OVERALL PROJECT OUTCOME AND RESULTS

A comparison between the hydrology of the Glacial Ridge National Wildlife Refuge before and after wetland and prairie restoration shows substantial changes in flows of water through the hydrologic cycle, in behavior of overland runoff and ditchflow during storms, and in water quality. Within the 6 basins measured for this study, the area of cropland decreased by 14 percent, the area of wetlands increased by 6 percent, and the area of native prairie increase by 19 percent between 2002 and 2015 due to restorations. During the same period, hydrologic changes had the benefits of decreasing runoff rate (-33 percent, as a proportion of precipitation) and ditchflow rate(-23 percent) and improving water quality as measured by nitrate concentration (surficial groundwater median: -79 percent, ditchwater median: -53 percent) and suspended sediment in ditchwater (-64 percent) within the study area. Peak ditchflow from storms decreased, ditchflow recessions lengthened, and baseflow from groundwater discharge increased, though only a small amount. These changes reduce the amount of water leaving the study area through ditches, reducing flows that contribute to flooding.

Neither the density of restorations nor the beneficial changes in hydrology were evenly distributed throughout the study area. Amount of hydrologic benefits within an individual ditch basin did not correlate directly with amount of restoration in that basin. This is likely because of complicating factors within each basin like the kind of land restored, the amount of surficial aquifer, the amount of remaining ditches, and the density of closed wetland and lake basins.

An analysis of landscape characteristics that correlated with hydrologic benefits in the study area showed that area of surficial aquifer and area of drained wetlands are most important. Surficial aquifers provide a groundwater reservoir that can reduce runoff and slowly release water as baseflow to streams. Drained wetlands simply provide the opportunity for restoration of closed basins, which reduces streamflow. Areas with the highest density of surficial aquifers and drained wetlands have the highest potential for hydrologic benefits from prairie and wetland

restoration. In western Minnesota, these areas are the uplands the Alexandria Moraine Complex and the beaches of Glacial Lake Agassiz on the eastern side of the western third of Minnesota, north of Wilmar, MN (Cowdery and others, 2017).

Cowdery, T.K., Christenson, C.A., and Zeigwied, J.R., 2017, The hydrologic benefits of wetland and prairie restoration in western Minnesota: lessons learned at the Glacial Ridge National Wildlife Refuge, 2002–15: U.S. Geological Survey Scientific Investigations Report 2017-xxxx, in preparation.

PROJECT RESULTS USE AND DISSEMINATION

The information generated by this grant will be documented in a U.S. Geological Survey Scientific Investigations Report that is in preparation. A draft of the report is attached to the project workplan. We expect the final draft of the report will be completed by 15 August, 2017. The report must be reviewed and approved, which we expect will occur by 31 October 2017. Once published, we will issue press announcements of the project results regionally and nationally. Additionally, the information in this report will be presented at several scientific meetings including that of the Minnesota Groundwater Association, the Minnesota Water-Resources Conference, and at annual conference of either the Geological Society of America or the American Geophysical Union. Presentations of interim result from this project have already been presented at meetings of the Minnesota Groundwater Association, the past Minnesota Water-Resources Conferences.

Project Completed: 06/30/2017 [Extended in M.L. 2015, Chapter 76]

[FINAL REPORT](#)

Subd. 04 Aquatic and Terrestrial Invasive Species

Blocking Bighead, Silver, and Other Invasive Carp by Optimizing Lock and Dams - RESEARCH

Subd. 04a \$854,000 TF

Peter Sorensen

U of MN

135 Skok Hall

2003 Upper Buford Circle

St Paul, MN 55108

Phone: (612) 624-4997

Email: soren003@umn.edu

Web: <http://fwcb.cfans.umn.edu/sorensen/>

Appropriation Language

\$854,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to collaborate with the United States Army Corps of Engineers to develop ways, including new technologies, to modify the operations of Lock and Dam Numbers 2 to 8 to optimize their ability to impede invasive carp movement into the Minnesota, St. Croix, and Mississippi Rivers. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Invasive carp species, including silver carp and bighead carp, are migrating north up the Mississippi River and pose threats to the native fish and aquatic ecosystems of Minnesota rivers and lakes where they can become established. While individual carp have been found in Minnesota, it is not presently believed that there are established breeding populations in the state. Nevertheless, the only current impediments to the upstream travel of carp into Minnesota waterways are the various lock and dam systems located between the Iowa border and the Twin Cities and these systems do not create a constant barrier to carp passage. Researchers at the University of Minnesota, in cooperation with the U.S. Army Corps of Engineers, are using this appropriation to develop and test ways to modify and optimize the operations of the existing lock and dam systems in order to enhance their ability

to deter and block carp passage without detrimentally affecting native fish or current lock and dam function. These efforts have the potential to delay or even prevent statewide invasion by invasive carp in Minnesota via the Mississippi River.

OVERALL PROJECT OUTCOME AND RESULTS

We successfully collaborated with the United States Army Corps of Engineers (USACE) and developed new ways and technologies to impede the upstream movement of invasive (bigheaded) carp through their locks and dams in the Mississippi River. Further, these approaches have now been implemented at Lock and Dam #8, which is the southernmost Lock and Dam in Minnesota and has thus been our focus. At this structure, dam spillway gate operating protocols were adjusted by the USACE to optimize their ability to stop carp and speakers added to the lock gates to deter carp with few effects on native fish. This is the first structure in the world to be so modified and our calculations suggest it now stops twice as many carp as it once did (well over 90%). Tentative plans for similar modifications to Lock and Dams #2 and #5 (the other most promising structures in Minnesota) have also been presented to the USACE for future deployment at their discretion. This progress was possible because we met all four objectives of this project: 1) we added speakers to Lock and Dam #1; 2) we quantified and published how well bigheaded carp swim (and thus what flows might stop them); 3) we developed and tested several new acoustic systems in the laboratory and field that stop carp but do not affect native fish ; and 4) we developed new solutions for the gates at Lock and Dam #2-8 and provided specific data (specific solutions) for Locks and Dams #5 and #2, the most promising structures of these.

PROJECT RESULTS USE AND DISSEMINATION

Our findings were disseminated via several dozen presentations to both professional scientific and lay groups across both the state and country, as well as four peer-review publications in high quality international journals. The speakers we installed at Lock and Dam #8 are still operating where they stop carp and have inspired the USACE and USFWS to mount similar speaker systems elsewhere while the DNR funded studies of their performance. Meanwhile, the published data we generated on silver and bigheaded carp swimming performance serves as the foundation of computational models to guide changes in gate operations to stop carp. In addition, the sound systems we identified as having special promise for stopping carp are now being considered for installation as part of a proof-of-concept project in both Minnesota (ENRTF, USFWS) and either Illinois or Kentucky (USFWS). Finally, our computational models are guiding gate operations that are presently both stopping carp and reducing scour at Lock and Dam #8. There is active interest by the USFWS to deploy our work downstream to further protect our state and region.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Bubble Curtain Deflection Screen Diverts the Movement of both Asian and Common Carp](#)

[Silver, bighead, and common carp orient to acoustic particle motion when avoiding a complex sound](#)

[Swimming performance of adult bighead carp and silver carp](#)

Bioacoustics to Detect, Deter and Eliminate Silver Carp - RESEARCH

Subd. 04b \$262,000 TF

Allen F. Mensinger

U of MN - Duluth

1035 Kirby Dr

Duluth, MN 55812

Phone: (218) 726-7259

Email: amensing@d.umn.edu

Web: <http://www.d.umn.edu/biology/faculty/mensing.html>

Appropriation Language

\$262,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota-Duluth to develop bioacoustics technology for detection and early warning systems, capture and elimination methods, and deterrent systems for silver carp. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Silver carp are migrating north up the Mississippi River and pose threats to the native fish and aquatic ecosystems of Minnesota rivers and lakes where they can become established. Additionally, the unique jumping ability of silver carp also places recreational boaters in danger of being injured during collisions with airborne fish. However, it is believed that this jumping ability could potentially be exploited as a weakness to help detect, manage, and control silver carp populations. Researchers at the University of Minnesota - Duluth, in cooperation with the U.S. Geological Survey, are using this appropriation to develop bioacoustics technologies that use sound to stimulate silver carp jumping in order to assist with strategies for detection, capture, and deterrence.

OVERALL PROJECT OUTCOME AND RESULTS

The project examined various emerging technologies to detect and deter the upstream migration of invasive bigheaded carp into Minnesota. Both silver and bighead carp were found to have an aversion to broad band sound and the project focused on how to exploit this weakness. An early detection buoy was developed that stimulates silver carp jumping with sound to allow managers to locate fish. The hearing sensitivities of the fishes were examined and found to have higher frequency hearing than previously reported. Broadband sound was successful in deterring fish and also preventing them from entering a small channel. Fish were successfully herded by broadband sound in the wild, suggesting that sound could be used to increase capture rates. We have also noted that long sound exposure may cause transient hearing losses in fishes so the sound deterrence must be balanced against potential hearing loss. In summary, broadband sound induces aversive behavior in silver and bighead carp however further study is needed to address the duration of its effectiveness.

PROJECT RESULTS USE AND DISSEMINATION

Presentations have been made at state, regional and national scientific meetings to disseminate the data and five publications were produced.

Project Completed: 06/30/2017

FINAL REPORT

[Acoustical deterrence of Silver Carp: Publication](#)

[Characterization and management implications of silver carp: Publication](#)

[Reexamining the frequency range of hearing in silver and bighead carp: Publication](#)

[Acoustic deterrence of bighead carp to a broadband sound stimulus: Publication](#)

[Management implications of broadband sound in modulating wild silver carp behavior: Publication](#)

[Potential implications of acoustic stimuli as non-physical barrier to silver carp and bighead carp: Publication](#)

Biosurveillance and Biocontrol of Emerald Ash Borer - Phase 2

Subd. 04d \$447,000 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/plants/pestmanagement/eab/eabbiocontrol.aspx>

Appropriation Language

\$447,000 the second year is from the trust fund to the commissioner of agriculture in cooperation with the University of Minnesota to continue to monitor ash tree and emerald ash borer populations and expand the biological control implementation for emerald ash borer management. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

The Emerald Ash Borer (EAB) is an invasive insect that has been decimating ash trees throughout the Great Lake states and is currently advancing into Minnesota where it threatens the nearly 1 billion ash trees that occur throughout the state - the second most in any state. Loss of these trees would devastate ecosystems throughout Minnesota and have major economic impacts for the forest products industry as well as through the costs associated with treatment, removal, and replacement of lost trees. Biological control - the use of a natural enemy of a species from its native habitat to help with control of that species - is currently the only promising long-term management strategy for EAB. The Minnesota Department of Agriculture is using this appropriation to continue to implement and assess the effectiveness of a biocontrol method for EAB in Minnesota that involves the use of tiny, stingless wasps that are parasitoids of EAB.

OVERALL PROJECT OUTCOME AND RESULTS

Emerald ash borer (EAB) populations have grown slower than expected in the Twin Cities metro region. To date, the insect has not spread as quickly in Minnesota as in other states. We were able to characterize this growth phase well with the continuing study on the infestation core commenced in Phase I of this project. Using annual branch sampling, we showed that after a decade of EAB presence in the Twin Cities metro region, half of the trees in the core area still did not exhibit easily-detectable levels of EAB, and canopy conditions remained quite good. We expect that EAB mortality due to extreme cold during the winter of 2013-2014 helped slow population growth. This slow growth continued to buy the state valuable time for implementing biological control and engaging the public in the fight against this insect, two other important strategies funded by this project. An astounding total of 450,000 larval and egg parasitoids were released at 33 sites during Phases 1 and 2 of this project. We are pleased that we documented established, reproducing populations of biological control agents at 5 sites in 2 counties. To document this, both larval parasitoids and the egg parasitoids were recovered with methods involving debarking ash branches and trunks, bark sifting, yellow pan traps and larval dissection. We also documented a native parasitoid, *Atanycolus simplex*, which can also attack EAB. We engaged a total of 128 citizen scientists using the biosurveillance program with smokey winged beetle bandit wasps, and collected more than two dozen species of buprestid beetles brought back to the nests by these wasps. We recovered ten species of *Agrilus* (in addition to EAB), providing important survey information on what other potential damaging wood borers in this family are present in the state. *Agrilus coxalis* is killing oaks in California, for example, but we have not found it in Minnesota to date.

PROJECT RESULTS USE AND DISSEMINATION

Our newly updated EAB management guidelines will be a valuable resource for people planning for or actively managing EAB. We incorporated findings from the project titled Improving EAB Detection in addition to Phase 1 and Phase 2 of our project. These guidelines provide information regarding EAB identification and reporting, detection methods and their relative efficiencies, recommended management tactics, including biocontrol, based on the infestation and site specifics. The guidelines will soon be available on MDA's EAB webpages (<https://www.mda.state.mn.us/emeraldashborer>).

We will build upon our accomplishments and learning with Phase 3: Assessment and Citizen Engagement.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[UMN Wasp Watcher Training Materials](#)

[UMN Wasp Watcher 2015 Field Report](#)

[UMN Wasp Watcher 2016 Field Report](#)

[UMN Wasp Watcher Pamphlet](#)

[MDA EAB Management Guidelines](#)

[MDA EAB Biocontrol Fact Sheet](#)

[MDA Biological Control of EAB: Bark sifting for *Oobius agrili*](#)

Mountain Pine Beetle Invasive Threat to Minnesota's Pines

Subd. 04e \$250,000 TF

Subd. 04e1 - \$175,000 TF

Brian Aukema

U of MN

1980 Folwell Avenue

St Paul, MN 55108

Phone: (612) 624-1847

Email: brianaukema@umn.edu

Web: <https://www.forest-insects.umn.edu/>

Subd. 04e2 - \$75,000 TF

Mark Abrahamson

Minnesota Department of Agriculture

625 Robert St N

St Paul, MN 55108

Phone: (651) 201-6505

Email: mark.abrahamson@state.mn.us

Web: <http://www.mda.state.mn.us/home.aspx>

Appropriation Language

\$175,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota and \$75,000 the second year is from the trust fund to the commissioner of agriculture to survey for the presence and characterize the potential risk of the invasive mountain pine beetle to Minnesota's pine forests to inform early detection and rapid response. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Native to the western United States and Canada, mountain pine beetle is considered the most devastating forest insect in North America. Trees usually die as a result of infestation and an unprecedented outbreak in the west is currently decimating pine forests there. While mountain pine beetle is not presently believed to reside in Minnesota, there are risks posed by an expanding species range resulting from warming climate and the potential for accidental introduction via lumber imports from infested areas. It is estimated that Minnesota currently has about 200 million trees that would be susceptible to mountain pine beetle if it should become established here and loss of those trees would threaten wildlife habitat, water quality protection, and recreation. Researchers at the University of Minnesota and the Minnesota Department of Agriculture are using this appropriation to survey state locations for the presence of mountain pine beetle and to characterize the risk posed by the insect to Minnesota pine species. If detected early enough isolated populations of mountain pine beetle may be possible to control and a better understanding of how Minnesota's particular pine species might react to the insect would guide future management response strategies.

U of M Project: OVERALL PROJECT OUTCOME AND RESULTS

Native to the western United States and Canada, mountain pine beetle is the most devastating forest insect in North America, impacting almost 125 million acres of western mature pine forests to date. Mountain pine beetle reproduces under the bark in the water conducting tissues of many species of pines. During outbreaks, mountain pine beetles must kill their trees in order to reproduce and prefer live, vigorous, large-diameter trees. Minnesota is at risk of invasion from mountain pine beetle via two different routes. First, populations reproducing in Alberta,

Canada could spread through a corridor of jack pine stretching across Canada's boreal forest into northern Minnesota. Second, green pine logs imported from western states could inadvertently bring this insect to the Midwest.

This project, in partnership with the Minnesota Department of Agriculture, had two objectives. First, pine stands in several areas of the state were surveyed for the presence of this insect. No populations were detected to date (see MDA update). Second, we exposed logs of pine species common in Minnesota, such as red pine, jack pine, white pine, and Scots pine, to the nearest known mountain pine beetle populations in the Black Hills of South Dakota, to gain baseline data on the risk to Minnesota's species of pines.

We found that mountain pine beetles were able to tunnel into cut logs of Minnesota's pines, attract mates, and lay eggs. The eggs were fertile, and insects could complete their development. The insects were cold hardy and the data suggest they could survive Minnesota's winters if established here. Development times in Minnesota's pines were slightly faster than those in historical western pine hosts, which was surprising. These results indicate that we should continue to take the threat of range expansion of mountain pine beetle seriously.

U of M Project: PROJECT RESULTS USE AND DISSEMINATION

During the course of this project, the MDA enacted an exterior state quarantine for pine logs with bark on them from western states, and the project manager met with DNR officials to discuss management/silvicultural responses to mountain pine beetle should the insect arrive in the state. This project fostered collaborations with five partner state and federal agencies, three universities, trained a PhD student who received a faculty position, and engaged several dozens of undergraduate university students by incorporating this project into classroom education such as redesigned laboratory practical exercises. In one instance, we hosted an undergraduate student from a different state who flew to Minnesota to conduct her internship on this project (at no cost to the project). If you are a student seeking to help with one of the most serious pending challenges in North America, the state of Minnesota is a great place to come! This research project has resulted in five peer-reviewed publications to date, with others currently in review, along with several presentations at various scientific conferences.

MDA Project: OVERALL PROJECT OUTCOME AND RESULTS

Mountain pine beetle (MPB), is native to western North America, where periodic outbreaks are a normal part of its ecology; in recent years, however, MPB has experienced the largest population explosion ever recorded and has caused the mortality of approximately 125 million acres of coniferous forest in North America. There is concern that MPB may reach Minnesota and cause similar devastation. Adult beetles have been shown to attack many different species of healthy pines including some that are found in Minnesota.

Mountain pine beetle has been detected in Minnesota two times in recent past: in 2012 in lodgepole pine from Montana for log cabins and furniture building and in 2014 in pine firewood from Wyoming for retail sale. In both cases, the insects were dead; however, this demonstrated the existence of a pathway across the plains for MPB to enter Minnesota. Interviews with wood product businesses in Minnesota indicated past instances where western pine had been imported as well. As a result, the MDA began conducting a detection survey in 2014 to determine if low-level populations of MPB are present. Lindgren funnel traps baited with pheromone lures were checked at sites near businesses such as log home and furniture builders and sawmills for 3 consecutive field seasons. Twenty five sites were chosen and 5 traps per site were monitored bi-weekly throughout the field season. Trap catches were screened for presence of mountain pine beetle. Subsamples of captures were also kept to better characterize the community of potential predators, parasitoids, and other associates already present in Minnesota. A total of 2150 trap checks were conducted from 2014-2016, fortunately no mountain pine beetle were detected. Estimating the arrival of MPB is difficult, thus monitoring is an important part of informing land managers so that management of isolated, endemic populations may be attempted.

MDA Project: PROJECT RESULTS USE AND DISSEMINATION

Dissemination of information from the monitoring portion of this mountain pine beetle project was ongoing through the entire three years 2014-2017. Staff participated in a variety of events with an emphasis on MPB. Our presence at trade shows, conferences, and community events provided unique and valuable opportunities to

interact with different audiences in-person. We attended more than 20 events, where we interacted with over 13,000 people. At these events we specifically focused on invasive pest and pathogens. Three of the most trafficked events attended include the Minneapolis Home and Garden Show, whose audiences included families, gardeners, and outdoors enthusiasts; the Minneapolis/St. Paul RV and Camping Show, whose audiences included outdoors enthusiasts, families, and firewood users; and a Minnesota Twins Plaza Day, whose audiences included homeowners. Information and materials related to MPB were displayed and distributed to event visitors. Materials produced for events included updated flyers, wallet-sized identification cards, display boxes, brochures and fact sheets. In addition, web pages focused on MPB and related surveys were added and updated as part of a larger, ongoing development project aimed at improving user experience. Cooperators, the public and the forest industry were also engaged and updated via phone, email, and through personal encounters in the field. Information and data was also continually updated throughout the project on the MDA MPB webpage: <https://www.mda.state.mn.us/plants/insects/mpb.aspx>

Project Completed: 06/30/2017

[FINAL REPORT - Aukema - \(Subd. 04e1\)](#)

[Colonization behaviors of mountain pine beetle - \(Subd. 04e1\)](#)

[Stimulating Curiosity and Engagement with Insects - \(Subd. 04e1\)](#)

[Cold tolerance of mountain pine beetle among novel eastern pines - \(Subd. 04e1\)](#)

[Sexing live mountain pine beetles - \(Subd. 04e1\)](#)

[FINAL REPORT - Abrahamson - \(Subd. 04e2\)](#)

[Mountain Pine Beetle Fact Sheet - \(Subd. 04e2\)](#)

Brown Marmorated Stink Bug Monitoring and Biocontrol Evaluation

Subd. 04f \$266,000 TF

Subd. 04f1 - \$167,000 TF

Robert Koch

U of MN

1980 Folwell Avenue

St Paul, MN 55108

Phone: (612) 624-6771

Email: koch0125@umn.edu

Web: <http://www.entomology.umn.edu/People/GradFaculty/Koch/index.htm>

Subd. 04f2 - \$99,000 TF

Mark Abrahamson

Minnesota Department of Agriculture

625 Robert St N

St Paul, MN 55108

Phone: (651) 201-6505

Email: mark.abrahamson@state.mn.us

Web: <http://www.mda.state.mn.us/plants/insects/stinkbug.aspx>

Appropriation Language

\$99,000 the second year is from the trust fund to the commissioner of agriculture and \$167,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to monitor for brown marmorated stink bugs to identify problem areas, target biocontrol efforts, and evaluate the suitability of candidate biological control

agents for use in Minnesota. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Brown marmorated stink bug is a terrestrial invasive species in Minnesota that was first discovered in 2010 and has been expanding its range since. It is a generalist plant pest that attacks more than 300 species of plants in natural, agricultural, and horticultural settings and is known for its unpleasant odor, large numbers, and propensity for home invasion. Proactive management approaches are available and in development that can be used to slow and potentially control brown marmorated stink bug populations. Researchers at the Minnesota Department of Agriculture and the University of Minnesota are using this appropriation to establish a state framework for monitoring and biological control of brown marmorated stink bug; efforts will focus on identifying new infestations and potential problem locations and evaluating and implementing biological control options.

U of M: OVERALL PROJECT OUTCOME AND RESULTS

The brown marmorated stink bug (BMSB), a pest of numerous crops and nuisance household invader, continues to spread and increase in abundance in Minnesota. Biological control offered by tiny parasitic wasps that attack BMSB eggs is a promising tactic for sustainable management of this pest. This project aimed to evaluate and identify appropriate biological control agents for use against BMSB in Minnesota before the pest reaches damaging levels. This work was performed as a successful collaboration with USDA. In particular, we used laboratory methods for quantifying the temperatures at which insects freeze and die to examine the ability of the candidate biological control agents to survive cold winter conditions. Methods were developed to measure the response to cold temperature of several populations of two species of parasitic wasps of BMSB. Among these, the samurai wasp is the primary species of interest for biological control releases and is already known to occur in parts of the USA. Results indicated that the samurai wasp likely to survive cold winter conditions of much of Minnesota and is better able to survive exposure to cold than BMSB. Furthermore, results of a broader modeling effort showed a south to north gradient of climatic suitability for the samurai wasp in Minnesota ranging from high to marginal suitability. Therefore, based on comparison of specific cold hardiness parameters and more complex modeling, the samurai wasp is likely to survive if introduced to Minnesota, and could provide for more sustainable management of BMSB than the current use of insecticides. In addition, this project prepared the State for implementation of biological control against BMSB by identifying and optimizing cold storage methods and conditions for mass production of the samurai wasp for biological control releases against BMSB.

U of M: PROJECT RESULTS USE AND DISSEMINATION

Results of this project were disseminated to scientific and grower audiences. For scientific audiences, results on the ability of biological control agents for BMSB were published in scientific article (Nystrom Santacruz et al. 2017, <https://doi.org/10.1016/j.biocontrol.2017.01.004>) and publication of additional results related to cold storage and mass production of the samurai wasp will be published soon. In addition, research was disseminated through multiple oral presentations at conferences of the Entomological Society of America and seminars at the U of MN. To reach audience of growers and the general public, results of this research have been included in several extension presentations to growers and crop consultants. Furthermore, the research stimulated attention and interviews by local media (<http://www.startribune.com/local/262464751.html?page=1&c=y> and <http://kstp.com/article/stories/S3469363.shtml?cat=26>). While working on this project, it was observed that there was a general lack of accessible information on the biology and management of BMSB and other stink bugs for crop and land managers. Therefore, we wrote and published an extension-friendly article on these topics in the Journal of IPM (Koch et al. 2017, <https://doi.org/10.1093/jipm/pmx004>), which also received considerable media attention.

MDA Project: OVERALL PROJECT OUTCOME AND RESULTS

Brown marmorated stink bug (BMSB) was first discovered in Minnesota in 2010. BMSB is a generalist that will feed on 300+ species of plants in natural and agricultural settings. Due to its large size and unpleasant odor, BMSB is also a nuisance home invader during the winter months. Based on experience with BMSB in other areas of the country, BMSB is expected to first become a household nuisance and then become a significant plant pest. MDA aimed to monitor BMSB to help track where problem areas are developing.

When MDA started this project in 2014, BMSB had been identified in 11 counties and has now been identified in 18. The goal of this project was to create a network of survey sites and place pheromone baited mini-tedder traps to detect BMSB and alert stakeholders to allow for targeted management. Traps were placed in the spring, serviced throughout the summer and removed in late October or early November 2014- 2016 and spring of 2017. Over the course of the monitoring project, MDA placed and serviced 690 mini-tedder traps throughout the state. Trap catches were low the first two years of the project with one adult captured in 2014 and 2 captured in 2015. MDA did respond to increasing reports of BMSB throughout the state despite low trap catches these years. Most of these reports were of single insects that were likely brought into the state from elsewhere. In the fall of 2016, MDA trapped 200 adult BMSB and 47 nymphs between 9 locations in the metropolitan area.

The increase in reports of BMSB and trap catches, including nymphs, indicates growing activity in the metro area which this project was able to document. This information provides an opportunity to proactively focus biocontrol efforts in this area and provides an opportunity to avoid reactive use of insecticides by growers.

MDA Project:PROJECT RESULTS USE AND DISSEMINATION

Dissemination of information and data about BMSB has been ongoing throughout this entire project. Presentations were given at Minnesota Fruit and Vegetable Growers Association annual meetings, the Minnesota Organic Conference, the Minnesota Apple Growers Association annual meeting, and Forest Pest First Detector Trainings. Growers were engaged and updated via phone, email, special mailings such as the Minnesota Department of Agriculture's Plant Pest Insider, and through personal encounters in the field.

Throughout the project, the MDA has maintained online maps regarding the status of BMSB

- Current BMSB activity:<https://www.mda.state.mn.us/plants/insects/stinkbug.aspx>
- Activity in past years: <http://www.mda.state.mn.us/plants/insects/stinkbug/bmsbmonitoring.aspx>

Project Completed: 06/30/2017

[FINAL REPORT - Koch: \(Subd. 04f1\)](#)

[Identification, Biology, Impacts, and Management of Stink Bugs: Publication \(Subd. 04f1\)](#)

[Cold tolerance of *Trissolcus japonicus* and *T. cultratus*: Publication \(Subd. 04f1\)](#)

[FINAL REPORT - Abrahamson: \(Subd. 04f2\)](#)

[BMSB Fact Sheet - Abrahamson: \(Subd. 04f2\)](#)

[BMSB MDA Presentation - Abrahamson: \(Subd. 04f2\)](#)

Subd. 05 Foundational Natural Resource Data and Information

Update Statewide Land Cover Use Map

Subd. 05a \$300,000 TF

Joseph Knight

U of MN

1530 Cleveland Ave N

115 Green Hall

St. Paul, MN 55108

Phone: (612) 625-5354

Email: jknight@umn.edu

Web: <https://rs.umn.edu/>

Appropriation Language

\$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to update Minnesota's land cover data at moderate spatial resolution statewide and at high resolution for selected areas,

distribute products, and provide training. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Land and water conservation efforts require accurate information about land cover and land use. Minnesota's land cover and land use data has not been updated since 2000 and so does not reflect changes since that time resulting from growth and development, agricultural production, or landscape cover. Researchers at the University of Minnesota are using this appropriation to conduct a statewide update and enhancement of land cover and land use data and make it freely available online for use by government and non-government organizations involved in land and water conservation.

OVERALL PROJECT OUTCOME AND RESULTS

Conservation and management of Minnesota's natural resources require significant investments of time and money by many state/local agencies and stakeholder groups. The three components of success in such projects (define problem sources, target and track changes) begin with accurate quantification of land cover via Geographic Information System (GIS) or geospatial data. This project updated the statewide land cover data and freely distributed it to all stakeholders. We acquired 130 Landsat satellite images for all of Minnesota for three broad seasons: Spring 2014, Summer 13-14 and Fall 13-14. The Landsat images were preprocessed according to current standards, including cloud correction, mosaicking, and subsetting. We acquired and preprocessed statewide lidar data. Preprocessing included developing Digital Elevation Models, Digital Surface Models, Normalized Digital Surface Models, and Normalized Digital Terrain Models. The imagery and lidar data were classified using an Object-Based Image Analysis (OBIA) approach, wherein the image pixels were aggregated into homogeneous "objects" that have parameters such as spectral values, size, shape, texture, and context. These variables were used in an OBIA classification framework incorporating a Cognition Language ruleset and the Random Forest algorithm to map each object into one of several classes: Forest (and sub-types), Urban (and sub-types), Wetland (and sub-types), Grassland, Extraction, and Agriculture. We produced statewide geospatial land cover/use data for 2013-2014, with higher resolution data for the Twin Cities Metro Area, Duluth, and Rochester. The classified maps have very high accuracy.

PROJECT RESULTS USE AND DISSEMINATION

All of the project data have been posted to the Minnesota Geospatial Commons (<https://gisdata.mn.gov/dataset/base-landcover-minnesota>), the Data Repository for the University of Minnesota (<https://conservancy.umn.edu/handle/11299/181555>), and the UMN Remote Sensing and Geospatial Analysis Laboratory (<https://rs.umn.edu/datalayers>) websites. A full project report has been provided separately. We have announced the availability of the data using several methods: via email, in person, in presentations at the MN GIS/LIS conference, and other communications. We regularly receive positive comments from users of the data. Scientific journal articles are in preparation.

Project Completed: 06/30/2017

[FINAL REPORT](#)

**State Spring Inventory for Resource Management and Protection
Subd. 05b \$200,000 TF**

Jim Berg

MN DNR

500 Lafayette Rd

St. Paul, MN 55155

Phone: (651) 259-5680

Email: jim.a.berg@state.mn.us

Web: <http://mndnr.gov>

Appropriation Language

\$200,000 the second year is from the trust fund to the commissioner of natural resources to develop necessary protocols, processes, and definitions of springs along with limited field testing of inventory procedures in priority areas to enable a systematic inventory of springs statewide needed to maintain spring flows and protect groundwater-dependent resources. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Natural springs occur throughout Minnesota and provide critical services for the state, such as creating trout streams and cool water fisheries, sustaining base flows in streams, creating unique ecological habitats, and maintaining the integrity of aquatic ecosystems against invasive species. In order to protect springs and the groundwater-dependent resources that depend on them, though, it is important to understand spring locations and status - information that is currently lacking in many areas of the state. The Department of Natural Resources is using this appropriation to establish a foundation and plan to systematically inventory, assess, and monitor spring resources throughout the state.

OVERALL PROJECT OUTCOME AND RESULTS

The purpose of this project was to initiate a systematic inventory of springs statewide. This inventory should help create awareness of and appreciation for this resource so spring flows can be maintained and groundwater-dependent resources can be protected. This phase of the inventory focused on developing protocols and methods for field work and data compilation along with limited field testing of inventory procedures. Major project objectives included the development of 1) a spring inventory guidance document to provide documentation of methods and guidance for other researchers; 2) a spring inventory database built on a web-based geographic information system (GIS) platform that can be used in the field with a computer tablet with GPS and cell phone data capabilities; 3) a web-based reporting application that citizens can use to submit spring locations with smartphones or other mobile devices; and to 4) expand the known set of spring locations through paper and digital records review and a limited amount of fieldwork.

All of these objectives were accomplished. Important sections of the guidance document include a spring classification system and key data to collect in the field. The document also describes data flow/data verification methods for entering data into the database from historical documents, field entry of data with the tablet, and data processing of citizen submittals through the citizen reporting application. The custom GIS database allows the project team to upload data directly to a server from the field with a cell phone data link. Important data include: spring location, estimated flow rate, photos, and physical/chemical information. The citizen reporting application provides similar but more limited capabilities.

To date, the spring inventory team has uploaded approximately 500 locations to the inventory database with the tablet system. Approximately 100 possible spring locations have been submitted through the citizen reporting application and targeted mailings with self-addressed, postal paid postcards. These efforts, in addition to migration of existing data from an older database and extensive document review, have created an inventory that currently contains approximately 6,000 locations.

PROJECT RESULTS USE AND DISSEMINATION

The long-term strategy is to establish the Spring Inventory at DNR as an ongoing hydrologic cycle database on the same basis as the existing DNR stream gaging, groundwater level monitoring, climatology, and related hydrologic cycle databases.

This data can be accessed through the following link:

http://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 Completed: 06/30/2017

[FINAL REPORT](#)

[MDNR Minnesota Spring Inventory Guidance Document](#)
[Legacy Data in the Minnesota Spring Inventory](#)

Drainage Records Modernization and Statewide Geographic Information System Database
Subd. 05c \$230,000 TF

Tim Gillette

Board of Water and Soil Resources
520 Lafayette Rd N
St Paul, MN 55155

Phone: (651) 297-2907

Email: tim.gillette@state.mn.us

Web: <http://www.bwsr.state.mn.us/>

Appropriation Language

\$230,000 the second year is from the trust fund to the Board of Water and Soil Resources to develop a template and Web-based geographic information system (GIS) database portal to facilitate statewide modernization of public drainage records under Minnesota Statutes, chapter 103E, and integrate new specifications into existing drainage records modernization guidelines. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

There are currently more than 21,000 miles of drainage ditches and many thousands of miles of subsurface tile located throughout Minnesota and overseen by over 100 different local drainage authorities. Historically public records of these drainage systems have been maintained primarily in hard copy following differing protocols depending on local requirements. However, this antiquated approach limits the usability and accessibility of public drainage records creating various challenges for drainage management efforts. Modernizing drainage records involves creating and cataloguing electronic copies of the records. While many drainage authorities have begun at least some level of modernization, there is still much work to be done. The Board of Water and Soil Resources is using this appropriation to establish a standardized information system to house public drainage records in a consistent manner that integrates the data with overall statewide GIS data. The system will facilitate increased accessibility and usability to drainage records and benefit water planning, modeling, and management efforts.

OVERALL PROJECT OUTCOME AND RESULTS

Approximately 100 counties and watershed districts serve as public drainage authorities (DA) under Chapter 103E drainage law. Their public drainage system administration encompasses more than 21,000 miles of drainage ditches and many thousands of miles of subsurface tile. Historically, their drainage system records have been maintained primarily in hard copy forms using production methods and materials of the time. Many of these records are over a century old and are becoming faded and fragile. Drainage records modernization (DRM) typically begins with creation and cataloguing of electronic copies (scans) of drainage system records. Advanced levels of DRM includes creation of associated geographic information systems (GIS) data layers.

This project included the development of a DRM GIS Database Template along with data standards, and access via a web-based data portal for M.S. Chapter 103E public drainage system hydrographic information (drainage system location, type, alignment, dimensions, profile, and road crossings) on the Minnesota GeoCommons which is administered by the Minnesota Geospatial Information Office (MnGeo). The database Template is available upon request to BWSR by interested drainage authorities statewide through the GeoCommons (<https://gisdata.mn.gov/organization/us-mn-state-bwsr>). Template use requires that the drainage authority upload drainage system hydrographic information on a yearly basis. If a DA desires to receive competitive DRM cost-share, it will be required to use the Template.

This project also included the updating of the Drainage Records Modernization Guidelines first published in 2008 by the BWSR, which is available on the BWSR website.

http://www.bwsr.state.mn.us/drainage/drainage_records_guidelines.pdf

The GIS database template creation and the Drainage Records Modernization Guidelines update were accomplished in coordination with MnGeo and their subcontractor, Houston Engineering, Inc., in consultation with 3 focus groups and a diverse project advisory committee.

PROJECT RESULTS USE AND DISSEMINATION

To date the GIS database template and updated Drainage Records Modernization Guidelines have been shared at the Minnesota GIS/LIS Consortium Conference (8/16), the fall meeting of the Minnesota Association of Drainage Inspectors (MADI) (10/16), the annual meeting of the Minnesota Association of Watershed Districts (MAWD) (10/16), the annual meeting of Association of Minnesota Counties (AMC) (specifically the AMC Ag and Rural Development Committee) (12/16), and the Minnesota Association of Soil and Water Conservation Districts (12/16). Plans are being made to continue outreach in 2017. Presently drainage records modernization cost share is before the Minnesota Legislature in the form of a LCCMR appropriation. The outcome of that effort will help establish the form of future DRM outreach.

At present 3 drainage authorities have requested the DRM GIS Database Template. One of those has uploaded drainage system hydrographic information to the GeoCommons.

Project Completed: 06/30/2016

[FINAL REPORT](#)

[Drainage Records Modernization Guidelines](#)

Assessing Species Vulnerability to Climate Change Using Phenology

Subd. 05e \$175,000 TF

Rebecca Montgomery

U of MN

1530 Cleveland Ave N

St. Paul, MN 55108

Phone: (612) 624-7249

Email: rebeccam@umn.edu

Web: <https://mnpn.usanpn.org/>

Appropriation Language

\$175,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to compile and use historical datasets to assess change over time in the ecology of Minnesota species, identify vulnerable species, and inform management strategies for climate change. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

There is a critical need to understand how our natural resources are already responding to climate change in order to develop tools for projecting natural resource responses into the future and to devise plans for actions that can be taken in reaction to observed and predicted changes. Phenology - the timing of seasonal biological events such as budburst, flowering, bird migration, and leaf coloring - provides a tested indicator of climate change response by plants and animals. A rich source of phenology datasets exists independently throughout the state, but these datasets are not compiled in a centralized manner. Furthermore, ongoing collection of phenology data is a cost efficient task that, done in an organized manner, can continue to provide valuable long-term evidence of climate change response. Researchers at the University of Minnesota are using this appropriation to compile and analyze historical phenology datasets and to establish a statewide network to collect future phenology data. This information will be helpful in identifying plant and animal species vulnerable to climate change and enhancing

adaptive management strategies, such as for maintaining forest productivity, supporting plant pollination and reproduction, and supporting efforts to maintain the integrity of wildlife and fisheries populations.

OVERALL PROJECT OUTCOME AND RESULTS

Understanding how natural resources are responding to climate change and developing tools for projecting responses into the future represent critical needs for environment and natural resource management in Minnesota. Phenology, the timing of biological events such as budburst, flowering and bird migration, provides an excellent and tested indicator of climate change response. The objectives of this project included: identify species vulnerable to climate change, develop a network of observers to monitor phenology into the future, provide data to natural resource managers for developing adaptive strategies that sustain environmental quality in a changing climate. To achieve these objectives we analyzed historical records of phenology to understand past trends and trained citizen scientists to collect new data to test models and provide continued monitoring into the future. In total we digitized over 44,595 historical observations from around the state of Minnesota. We performed >25 statewide training seminars (~800 participants) and created online training materials and a website. The number of observers entering phenological data into Nature's Notebook went from 140 in 2015 to 1150 today. Minnesota now has the second most phenology observers by state, only surpassed by California. Observers come from all parts of the state (n=108 Northwest MN, 193 Northeastern MN, 59 Central MN, 85 Southern MN, and 703 in the Twin-cities Metro area). The growth in new observations has increased between 22-51% per year since the start of the project. Combining historical and current datasets yielded a total of 865,816 phenological observations. Our work is significant as one of the largest regional datasets documenting change in nature's cycles and seasons. The data is publicly available for natural resource managers and scientists to use in decision-making. Examining phenological trends through time, we've found a number of species that show earlier spring phenology and later fall phenology as predicted under climate change. Among notable animals, Sandhill Crane, Northern White Shoveler, American White Pelican and Eastern Towhee are arriving significantly earlier. For plants, apple, bur oak, American elm, quaking aspen, beaked hazel and red pine all show significantly earlier budburst. For many of these, events are happening 7-9 days earlier in than in the 1940s. On-going analyses in a Ph.D. thesis will highlight species that could be at risk in a changing climate and thus guide policy and decision-making.

PROJECT RESULTS USE AND DISSEMINATION

We created and made available an online, searchable database and visualization tool of historical data (<https://mnpn.usanpn.org/datasets>). This dataset has been downloaded 20 times to date. New data collected by citizen observers is publicly available through Nature's Notebook, a program of the USA-NPN (<https://www.usanpn.org/results/data>). Training videos and workshop materials are freely available via the Minnesota Phenology Network website. As described in our activity report and abstract, we conducted >25 presentations and workshops to ~ 800 people over the course of the project. We manage a Facebook page (Minnesota Phenology Network) on which we share results and create online community.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Minnesota Breeding Bird Atlas - Final Phase

Subd. 05f \$300,000 TF

Lee Pfanmuller

Audubon Minnesota

One West Water St., Suite 200

St. Paul, MN 55107

Phone: (612) 810-1173

Email: leefpann@msn.com

Web: <http://mn.audubon.org/>

Appropriation Language

\$300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Audubon Minnesota to complete a statewide survey of Minnesota's breeding bird distributions through final analysis, preparation, and dissemination of information collected on an ongoing basis since 2008 on breeding birds in the state. The completed atlas must be available for download from the Internet free of charge. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

A state Breeding Bird Atlas is a comprehensive systematic field survey of the occurrence, distribution, diversity, and breeding status of bird species within every region of a state. Atlases are mainly used to set conservation priorities, develop conservation plans, and guide habitat protection, restoration, and management efforts - in addition to being useful for recreational bird watching. Minnesota is one of only seven states in the country that has yet to complete a Breeding Bird Atlas. Audubon Minnesota and the Natural Resources Research Institute at the University of Minnesota - Duluth will use this appropriation to complete the Minnesota Breeding Bird Atlas. This phase involves analyzing and synthesizing over 350,000 observations collected since this effort began in 2008 and producing and disseminating related information products.

OVERALL PROJECT OUTCOME AND RESULTS

The Final Phase of the Minnesota Breeding Bird Atlas (MNBBA) analyzed field data collected during the five year atlas project and developed a website presenting the results. The MNBBA was a comprehensive, statewide survey on the breeding distribution for all bird species in Minnesota. Initiated in July 2008, it was a collaborative effort among Audubon Minnesota, the Minnesota Department of Natural Resources, the U.S. Fish and Wildlife Service, the Minnesota Ornithologists' Union, and the University of Minnesota's Natural Resources and Research Institute. The atlas encompassed 5 field seasons (2009-2013), involved nearly 700 volunteers and survey staff in data collection, and cataloged the distribution and relative abundance of 249 breeding species statewide down to the 1/4 township level. Similar initiatives have been conducted by states and provinces throughout North America. Specific project outcomes since July 2014 included: 1) a technical review of the 380,707 records collected during the atlas to insure data integrity; 2) development of 160 predictive distribution models that linked the distribution and abundance of breeding species with data on climate, habitat, and landscape context; 3) analysis of habitat associations for 130 of the most common species; 4) preparation of accounts for each of the 249 species that summarized their life history, conservation status, Minnesota distribution since the late nineteenth century, breeding habitat, and population abundance; and 5) development of a website (mnbirdatlas.org) that presents results for each species, including an interactive map that enables users to conduct a variety of geographic and ecological searches of the MNBBA data.

These data will be invaluable to conservation planning efforts by local, state, and federal agencies as well as non-governmental organizations as they plan and implement efforts that affect Minnesota's natural resources. As a historical record, the MNBBA also provides baseline data to monitor future changes in avian distribution and abundance.

PROJECT RESULTS USE AND DISSEMINATION

All project results, analyses, and interpretation will be displayed on the newly developed website no later than October 30, 2017 (mnbirdatlas.org). Audubon Minnesota will publicize the site's launch. In the interim, all data collected during the atlas continue to be displayed on the website that has serviced the project since the beginning, mnbba.org. Data collected by MNBBA volunteers and point count data collected by the Natural Resources Research Institute will also be displayed and housed by the Midwest Avian Data Center (<http://data.pointblue.org/partners/mwadc/>), a regional node of the Avian Knowledge Network (<http://www.avianknowledge.net>). A Data Sharing Agreement between Audubon Minnesota and the Avian Knowledge Network (AKN) outlines procedures for individuals interested in acquiring full or partial downloads of the original data. Users of the (<https://mnbirdatlas.org/>) website who wish to acquire data are directed to the AKN website. These same data also will be made available to the University of Minnesota's Minnesota Biodiversity Atlas maintained by the Bell Museum of Natural History.

Project Completed: 06/30/2017

FINAL REPORT

Sandhill Crane Populations and Management in Minnesota - RESEARCH

Subd. 05h \$250,000 TF

David Andersen

U of MN

200 Hodson Hall, 1980 Folwell Ave

St. Paul, MN 55108

Phone: (612) 626-1222

Email: dea@umn.edu

Web: <http://fwcb.cfans.umn.edu/Faculty/Andersen/index.htm>

Appropriation Language

\$250,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to delineate population boundaries, habitat use relative to crop depredation, and migration patterns and survival of Minnesota's two populations of sandhill cranes, Mid-continent and Eastern. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Sandhill cranes have expanded their range in Minnesota and elsewhere and as populations have expanded several states, including Minnesota, have initiated sandhill crane hunting seasons and other states are considering doing the same. Partially this is in response to increasing complaints of crop degradation by sandhill cranes. Despite expanding populations, though, sandhill cranes remain a species of management concern and current information on population distribution and migration patterns of sandhill cranes in Minnesota is insufficient for projecting the impact of hunting or for making informed management decisions. Researchers at the University of Minnesota are using this appropriation to conduct a survey to better understand population distributions, movement patterns, habitat usage, and survival of sandhill cranes in Minnesota in order to inform harvest and management strategies that will minimize conflict with agricultural interests.

OVERALL PROJECT OUTCOME AND RESULTS

Sandhill cranes are an important part of Minnesota's natural heritage, and although they have expanded their breeding range in Minnesota, they remain a species of management concern. Minnesota supports two populations of sandhill cranes– the Mid-continent Population that breeds and migrates through northwestern Minnesota, and the Eastern Population that breeds and migrates throughout much of the remainder of the state. We affixed GPS-cell transmitters to 55 sandhill cranes during 2014 and 2015 near the presumed boundary between breeding Mid-Continent and Eastern Population cranes in Minnesota and monitored their seasonal (i.e., migratory) and local movements to (1) determine whether Mid-Continent and Eastern Population cranes breeding in Minnesota overlap in breeding or autumn staging distributions, and if so, identify regions of overlap, (2) quantify habitat-use patterns, especially related to crop depredation, and (3) estimate annual survival rate of Minnesota sandhill cranes:

1. We identified areas of overlap between breeding populations in northwestern Minnesota, near the historical range boundary of Mid-Continent cranes, suggesting that Eastern Population cranes have expanded their distribution significantly northwest. Furthermore, cranes from both populations used fall staging areas in northwestern Minnesota in the current zone where recreational harvest of Mid-Continent Population cranes was allowed beginning in 2010, indicating at least some overlap of populations during Minnesota's crane hunting season. In addition, some cranes used migration routes associated with both populations, providing potential for population mixing outside of their breeding ranges.
2. At the local scale, adult and juvenile cranes used crops during both crepuscular and mid-day periods during spring (the peak period of crop depredation), with juvenile cranes exhibiting a stronger preference for crops during crepuscular periods, suggesting that juvenile cranes are more likely to engage in crop

depredation than adults. However, juvenile cranes exhibited considerable individual variation in their use of agricultural landscapes.

3. Finally, our estimates of annual survival rate of Minnesota cranes are consistent with other published estimates of crane survival rate, although because we had difficulty distinguishing mortality from transmitter failure, the uncertainty in our estimates is large.

Our study provides current information about the population affiliation of Minnesota sandhill cranes, and indicates that the recent dramatic growth in abundance of cranes in Minnesota is largely a consequence of an increase in the number and distribution of Eastern Population sandhill cranes in the state. There is overlap in the distribution of these two populations both on the breeding grounds, and to a lesser extent, during staging, migration, and winter, potentially complicating local management options. Conflicts caused by spring crop depredation are likely disproportionately due to juvenile cranes, and efforts to mitigate crop damage are likely to be most effective if targeted at cranes engaging in depredation, rather than at the entire population through hunting or other means. Generally high annual survival rates likely contribute to a growing Minnesota sandhill crane population, especially Eastern Population cranes.

PROJECT RESULTS USE AND DISSEMINATION

We presented our research results via four oral presentations and two poster presentations at professional conferences (the Annual Meeting of the Minnesota Chapter of The Wildlife Society, the Midwest Fish and Wildlife Conference, and the North American Crane Workshop). We presented two invited talks to the Minnesota Department of Natural Resources (the Waterfowl Committee and the Northwest Regional Wildlife meeting). We presented four invited talks in general public scientific settings (Brainerd Lakes Audubon Society, Minnesota Prairie Chicken Society, Maplewood Nature Center, and the Minnesota Waterfowl Association), and a public seminar at the University of Minnesota (Natural Resource Science and Management Graduate Seminar Series). We also gave a presentation to five kindergarten classes in the Mounds View School district. We currently have one manuscript accepted for publication and in press at the Wildlife Society Bulletin. We also digitally archived the data and programming code required to reproduce the analysis for this publication at the Data Repository for the University of Minnesota, which is part of the University Digital Conservancy. This research project was featured in articles in the following Minnesota newspapers and magazines:

1. Minnesota Study Focuses on Sandhill Cranes. Grand Forks Herald. Brad Dokken. May 17, 2015.
2. Crane Set Record, Prompt Research at Sherburne NWR. Saint Cloud Times. Ann Wessel. November 2, 2015.
3. The Resilience of Sandhill Cranes. Minnesota Conservation Volunteer. Carroll Henderson. March-April edition, 2016.
4. Study's Aim: Shed Light on State's Sandhill Cranes. Outdoor News. Joe Albert. July 22, 2016.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Imperiled Prairie Butterfly Conservation, Research and Breeding Program - RESEARCH

Subd. 05j \$625,000 TF

Subd. 05j1 - \$380,000 TF

Erik Runquist

Minnesota Zoo

13000 Zoo Blvd

Apple Valley, MN 55124

Phone: (952) 431-9562

Email: erik.runquist@state.mn.us

Web: <http://www.mnzoo.org>

Subd. 05j2 - \$245,000 TF

Robert Dana

MN DNR
500 Lafayette Rd Box 32
St. Paul, MN 55155
Phone: (651) 259-5086
Email: robert.dana@state.mn.us
Web: <http://www.dnr.state.mn.us>

Appropriation Language

\$380,000 the second year is from the trust fund to the Minnesota Zoological Garden and \$245,000 the second year is from the trust fund to the commissioner of natural resources to prevent the extirpation and possible extinction of imperiled native Minnesota butterfly species through breeding, genetics and mortality research, inventory, monitoring, and public education. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

With only 1% of Minnesota's native prairie remaining, many prairie plant and animal species have dramatically declined. Of the 12 butterfly species native to Minnesota prairies, two species, the Poweshiek skipperling and the Dakota skipper, have already largely disappeared from the state and are proposed for listing under the U.S. Endangered Species Act despite being historically among the most common prairie butterflies and having their historic ranges concentrated in Minnesota. The Minnesota Zoo and the Minnesota Department of Natural Resources are using this appropriation to conduct efforts aimed at preventing the extirpation and possible extinction of these butterfly species in Minnesota. Efforts will include expansion of both a butterfly research and conservation breeding program and ongoing butterfly survey and monitoring programs. Because of the ecological role of butterflies as pollinators and a food source for wildlife, analysis should also reveal important information about the greater prairie ecosystem and guide actions to be taken to protect it.

MN Zoo Project: OVERALL PROJECT OUTCOME AND RESULTS

Many of Minnesota's prairie butterflies are declining. Due to ENRTF support, the Minnesota Zoo's Prairie Butterfly Conservation Program has dramatically expanded the first and only conservation rearing and breeding programs for Minnesota's imperiled prairie butterflies. We developed new rearing and breeding techniques, and increased the Zoo's conservation population of U.S. Threatened (Minnesota Endangered) Dakota skippers from 44 adults in 2014 to over 375 adults in 2017. This expansion allowed for the beginning of a multi-year reintroduction program in 2017 when 200 Zoo-reared Dakota skippers were released to reestablish a lost Minnesota population. A new augmentation program is also underway to support some of the last United States populations of the Endangered Poweshiek skipperling.

The causes of these butterfly declines are not fully understood, many factors likely contributed, and some of those threats may still exist. The ENRTF provided critical funding though to begin understanding the potential role of insecticide drift into prairies. We produced foundational data on the extent, composition, and timing of pesticides drifting into critical habitats for these protected species. The findings inform hypotheses about what may have contributed to declines of these butterflies and have spurred additional research recommendations. We are working with other agencies and parties to advance risk assessments and proper habitat management and to reduce drift exposure.

The ENRTF supported foundational Dakota skipper and Poweshiek skipperling population genetics research, filling critical knowledge gaps that inform management of these butterflies at both in the Zoo and in the wild. These studies are being published in peer-reviewed scientific literature.

We developed new outreach about butterflies, prairies, and what the public can do to help. Thanks to the ENRTF, we published two popular pamphlets in both English and Spanish, and these have been distributed free to nearly 10,000 people at the Minnesota Zoo and at other events.

MN Zoo Project: PROJECT RESULTS USE AND DISSEMINATION

We have developed a large network of collaborators across local, state, national, and international levels. We hold frequent conference calls with several recovery and threat assessment working groups for both Poweshiek skipperling and Dakota skipper, and have attended and/or hosted several multi-day meetings and conferences for these species. We present our results to these working groups and other permitting agencies, and prepare detailed annual reports. Our results informs the actions and recommendations of the working groups. The foundational husbandry protocols we developed have also helped Winnipeg's Assiniboine Park Zoo launch a parallel and collaborative prairie butterfly conservation rearing and breeding program. Scientific products of our ENRTF-supported work will be submitted for peer-reviewed publication.

Thanks to the programmatic expansions supported by the ENRTF, the plight of prairies and their butterflies have become much more visible and publicly known. We have presented to dozens of general public audiences (thousands of people in total), and at several University undergraduate and graduate-level courses and seminars. At least nine newspaper, radio, and television stories have been produced about the prairie butterfly conservation efforts supported by the ENRTF since 2014, including four new newspaper, radio, and television stories associated with the Dakota skipper reintroduction program in the summer of 2017.

Minnesota Zoo Facebook Live streaming event from the Hole-in-the-Mountain Prairie Preserve (<https://www.facebook.com/mnzoo/videos/10155374215493788/>) featuring Prairie Butterfly Conservation Program manager Dr. Erik Runquist, the Minnesota DNR's Dr. Robert Dana (project lead on this joint ENRTF for Activity 3), and staff from The Nature Conservancy and the US Fish and Wildlife Service. Viewed nearly 11,000 times, the video provided a live look at the Dakota skipper reintroduction effort, the history of the ENRTF-supported Prairie Butterfly Conservation Program, and the partnerships involved. Additional Minnesota Zoo social media and blog posts were presented throughout the summer of 2017 highlighting the reintroduction effort, our "Plant For Pollinators" campaign, and the re-introduction of the Butterfly Brew Dakota Skipper Endangered Reserve promotion through Fair State Brewing Cooperative.

MN DNR Project: OVERALL PROJECT OUTCOME AND RESULTS

This project was a collaboration with the Minnesota Zoo to find the cause or causes of the recent precipitous declines of two prairie-dependent skipper butterflies, the Poweshiek skipperling and the Dakota skipper, and to restore both to a level of abundance that will assure their survival. These declines have prompted the U.S. Fish & Wildlife Service to list the Poweshiek skipperling as endangered and the Dakota skipper as threatened. The MN DNR was responsible for one of the project's component activities—surveying sites throughout MN's prairie region that historically supported these two butterflies as well as sites with appropriate habitat that had never been previously surveyed.

The goals of this survey were to determine if there were extant populations of these two species in Minnesota, to initiate monitoring of any populations found, and to survey for 11 additional butterfly species that are prairie-dependent or highly associated with native prairie in MN to determine whether they also show evidence of decline from historical levels. Surveys were conducted from July 1 through early September in 2014 and from early June through early September in 2015 and 2016.

A total of 63 sites throughout western Minnesota were surveyed one or more times, 44 in 2014, 51 in 2015, and 52 in 2016. Seven of the target species were not observed: Dusted skipper, Garita skipperling, Uhler's arctic, Iowa skipper, Ottoo skipper, Assiniboia skipper, and most significantly, Poweshiek skipperling, adding to the probability that this federally endangered species is extirpated in Minnesota. One population of the federally threatened Dakota skipper was confirmed to remain, and this population probably declined over the three survey years. Only two populations of the Pawnee skipper were located, one in same site as the Dakota skipper. Other species found were Gorgone checkerspot, Prairie ringlet, Melissa blue, and Regal fritillary. The results indicate a sharp decline from historical levels for Gorgone in the south half of the surveyed region and probable but weaker declines for the blue and the ringlet. Only the Regal fritillary appears to be resisting the trend.

MN DNR Project: PROJECT RESULTS USE AND DISSEMINATION

Two presentations: one to the annual Day of Insects symposium at Iowa State University in 2015, one to a workshop organized by the MN Zoo with the University of Minnesota on the possibility that insecticide contamination is a contributor to the declines. Interviews with reporters, one with the Fargo Forum newspaper, one with a MN Public Radio reporter resulting in some media coverage. Participation in a meeting organized by USFWS with land managers to discuss management strategies in the Felton Prairie. Presentation to the Clay County Board on the Dakota skipper presence in the Felton Prairie. The County owns the prime Dakota skipper habitat in the Felton prairie, and the presentation, along with ones by USFWS staff and other DNR staff, was to update them on the biological significance of the site. Annual reports to DNR Div. of Parks and Trails, Scientific & Natural Areas Program, The Nature Conservancy, the town of Fertile, MN, Clay County, USFWS, Morris Wetland District, The MN Zoo has made many presentations in which this survey work has been given some exposure.

Project Completed: 06/30/2017

[FINAL REPORT - Runquist: \(Subd. 05j1\)](#)

[Prairie Butterfly Conservation Program Annual Report - Runquist: \(Subd. 05j1\)](#)

[Plan for the Controlled Propagation, Augmentation, and Reintroduction of Dakota Skipper - Runquist: \(Subd. 05j1\)](#)

[MN Zoo Butterfly Brochure \(ENG\): \(Subd. 05j1\)](#)

[MN Zoo Butterfly Brochure \(SPA\): \(Subd. 05j1\)](#)

[MN Plant for Pollinators Brochure \(ENG\): \(Subd. 05j1\)](#)

[MN Plant for Pollinators Brochure \(SPA\): \(Subd. 05j1\)](#)

[FINAL REPORT - Dana: \(Subd. 05j2\)](#)

Conserving Minnesota's Native Freshwater Mussels - RESEARCH

Subd. 05k \$350,000 TF

Jessica Kozarek

U of MN

2 3rd Avenue SE

Minneapolis, MN 55414

Phone: (612) 624-4679

Email: jkozarek@umn.edu

Web: <http://www.safl.umn.edu/facilities/osl>

Appropriation Language

\$350,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with Macalester College to document native freshwater mussel abundance and distribution, quantify environmental conditions necessary to conserve Minnesota's native freshwater mussels, and conduct outreach to local organizations and the public. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

Project Overview

Though they are a relatively unnoticed group of species, native freshwater mussels are a critical part of river ecosystems because they provide a variety of important functions including improved water clarity, enhanced streambed stability, reduced downstream transport of contaminants, and creation of habitat for other aquatic life. However, mussel populations in Minnesota have declined in recent decades as a result of habitat destruction, pollution, land-use change, over-harvesting, and the introduction of exotic species. Researchers at the University of Minnesota are using this appropriation to conduct surveying and analysis to better understand mussel abundance, distribution, and interactions with habitats in order to guide efforts to preserve and restore native mussel populations and maintain the ecosystem services they provide.

OVERALL PROJECT OUTCOME AND RESULTS

Native freshwater mussels are a valuable part of Minnesota river ecosystems. Mussels can improve water clarity, enhance streambed stability, and create habitat for other aquatic organisms. Freshwater mussels are filter feeders that live within river bottom sediment and are sensitive to environmental changes including increased sediment loads, higher flood flows, or lower base flows. We investigated the interactions between mussels and their habitat using a combination of fieldwork in the Minnesota and the St. Croix watersheds and laboratory experiments in the Outdoor StreamLab and flumes at St. Anthony Falls Laboratory. We re-visited field sites previously sampled by MN DNR and evaluated mussel population change in abundance, diversity, life history traits and disturbance tolerance across a gradient of suspended sediment loads and agricultural impacts. We also evaluated growth rates and mussel energy stores (glycogen) within these watersheds. In general, as agricultural impacts (and sediment loads) increased, mussel abundance and diversity decreased, but growth rates and mussel energy stores increased, likely due to increased food availability from agricultural nutrient inputs. In addition, as agricultural impacts increased, mussel communities shifted toward more disturbance tolerant, opportunistic communities. In the laboratory, we evaluated mussel response to flow, suspended sediment, and streambed stability. Mussels did not stop feeding under high flows with increased sediment loads, and there was no measurable impact on mussel energy stores. However, mussels did increase their waste excretion behaviors. During flooding, when bed sediment was mobile, mussels anchored in place until flood waters receded. These experiments provide important evidence about how adult mussels respond to changing hydrology and sediment loads. However, sediment effects could not be isolated in the field and multiple stressors (hydrologic changes, sediment, nutrients, other pollutants, etc.) can affect sensitive mussel species and/or sensitive phases of the mussel life cycle. This research informs mussel conservation and re-introduction efforts.

PROJECT RESULTS USE AND DISSEMINATION

Through this project, we advocated cleaner and healthier Minnesota waters by studying the environmental conditions necessary to conserve and promote a diverse and sustainable native mussel population. This project impacted 1) the greater scientific community through the development of five peer-reviewed publications and presentations at scientific conferences (state, regional, and national); 2) water resources and wildlife professionals working towards freshwater mussel conservation through the dissemination of results, and 3) the general public through public engagement strategies designed to illustrate ecosystem services provided by freshwater mussels and the linkages between mussels and clean water. In addition, this project provided training for the next generation of water resource professionals by incorporating twelve undergraduate student researchers in field, laboratory, and engagement activities.

Project Completed: 06/30/2018

[FINAL REPORT](#)

[Issue Nine: Winter 2018 - Open Rivers: Rethinking Water, Place & Community](#)

[Issue Four: Fall 2016 - Open Rivers: Rethinking the Mississippi](#)

Impacts of Forest Quality on Declining Minnesota Moose - RESEARCH

Subd. 05I \$300,000 TF

James Forester

U of MN

2003 Upper Buford Circle

Suite 135

St. Paul, MN 55108

Phone: (612) 626-6721

Email: jdforester@umn.edu

Web: <http://fwcb.cfans.umn.edu/forester/index.html>

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 Department of Natural Resources to link regional patterns of moose abundance through time to the distribution of food and cover and determine if this distribution affects the diet and survival of individual moose. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Moose, one of Minnesota's prized wildlife species, are dying at much higher rates in Minnesota than elsewhere in North America. Recently observed increases in mortality rates amongst some moose in northeastern Minnesota have led to concern that the population there may be entering a decline like that seen in the northwestern part of the state, where moose populations fell from over 4,000 to fewer than 100 in less than 20 years. Additionally the specific causes of increased mortality amongst individual moose remain under investigation. Scientists at the University of Minnesota are using this appropriation to examine the role of habitat quality and landscape change and how it impacts moose diet, body condition, and mortality risk, specifically the role of forest age, structure, and composition in distribution of food and cover. Knowledge gained will be used by federal, state, and local natural resource agencies to identify appropriate management and habitat needs and actions that can be taken to help slow or prevent continued population declines in northeastern Minnesota of this iconic, keystone species.

OVERALL PROJECT OUTCOME AND RESULTS

We examined characteristics of land cover and forage quality that could be affecting the declining Minnesota moose population at multiple spatial and temporal scales. At a broad spatial scale, we found that the landscape of NE Minnesota has changed over 18 years, both in the composition (e.g., more coniferous and less mixed-wood forest) and arrangement (e.g., decreased fragmentation of coniferous forest and increased fragmentation of mixed-wood forest) of forested land-cover types. At the scale of the moose survey unit (2.8 x 5 miles), some of these changes appear to be related to moose population dynamics. Specifically, moose tended to have higher population growth rates in cooler areas and in survey units that had more young and mixed-wood forest, less coniferous and deciduous forests, and less fragmented forested wetlands. We found that, during summer, moose are in fact altering their behavior to seek out mixed-wood forest at the hottest times of the day, and because we found that forage availability differs both by cover type and by location in moose range, these decisions may be affecting diet. Further, because the diets of animals that died were different from those of live animals, we suspect that the availability of high-preference foods may be critical. Because several independent sources of data all point in a similar direction, we recommend a large-scale, long-term experiment to explicitly test how different combinations of land cover and food availability may be affecting moose habitat use and population dynamics. Specifically, we suggest working with forest managers to harvest blocks of forest stands to manipulate overstory and understory features that appear to be important to moose. Monitoring the success of these manipulations with collared animals and camera traps over a 5-10 year period could help determine how to best manage forest landscapes for a healthy moose population.

PROJECT RESULTS USE AND DISSEMINATION

This research has been presented 15 times at national or international research conferences or invited seminar series. The research team has worked with the Bell Museum to contribute information related to the moose diorama and also provided an extensive interview to the "Access Minnesota" radio show. Three scientific articles have been published so far, and the research team is working with MNDNR and tribal biologists to discuss the results and implications of this work. Finally, 12 undergraduate students, five graduate students, and three postdoctoral researchers received training as part of this project; results from this research have been added into teaching materials in two required Fisheries, Wildlife, and Conservation Biology courses at UMN.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Habitat functional response mitigates reduced foraging opportunity: Publication](#)

[Combinations of Abiotic Factors Differentially Alter Production of Plant Secondary Metabolites: Publication](#)

[Used-Habitat calibrations plots: Publication](#)

Moose Decline and Air Temperatures in Northeastern Minnesota - RESEARCH
Subd. 05m \$600,000 TF

Michael Larson

MN DNR

1201 E Hwy 2

Grand Rapids, MN 55744

Phone: (218) 328-8873

Email: michael.larson@state.mn.us

Web: <http://www.dnr.state.mn.us/moose/index.html>

Appropriation Language

\$600,000 the second year is from the trust fund to the commissioner of natural resources in cooperation with the University of Minnesota to study the physiology and behavior of adult moose and effects of female condition on calf production and survival to determine the impact of air temperature on moose population performance and decline. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Moose, one of Minnesota's prized wildlife species, are dying at much higher rates in Minnesota than elsewhere in North America. Recently observed increases in mortality rates amongst some moose in northeastern Minnesota have led to concern that the population there may be entering a decline like that seen in the northwestern part of the state, where moose populations fell from over 4,000 to fewer than 100 in less than 20 years. Additionally the specific causes of increased mortality amongst individual moose remain under investigation. Scientists at the Minnesota Department of Natural Resources are using this appropriation to help understand how air temperature affects moose habitat use and behavior, reproductive success, and survival in order to determine if, when, and how moose are able to successfully modulate internal body temperature. Knowledge gained will be used by federal, state, and local natural resource agencies to identify appropriate management and habitat needs and actions that can be taken to help slow or prevent continued population declines in northeastern Minnesota of this iconic, keystone species.

OVERALL PROJECT OUTCOME AND RESULTS

We used GPS collars, mortality implant transmitters (MITs), which continuously record internal body temperatures, and samples of moose urine voided in snow to study moose in northeastern Minnesota, a population that recently experienced significant declines.

Annual mortality rates of adult moose were 12–19% during 2013–2016, higher than the 8–12% rates reported in stable moose populations elsewhere in North America. The main causes of death for 57 moose were wolf predation (32%), parasites (30%), bacterial infections (21%), and other health issues (17%). MIT temperatures were 37.55–42.10°C in 25 moose; more MITs will be recovered later. Average daily MIT temperature increased 0.0009°C for every 1 degree increase in average daily air temperature. Twenty-three moose had 0.2–11% of internal temperatures considered above normal (i.e. $\geq 39.2^\circ\text{C}$). Habitat types used when an animal was hot compared to what was available was significantly different in some moose during summer.

The average pregnancy rate was similar to the North American average (83%). For GPS-collared calves born in 2013–2014 and unmarked calves (with collared mothers) born in 2015–2016 survival to 30 days of age was 58.4% and ~65%, respectively. By early spring survival declined to 34.1% and 33–40%, respectively. For 57 calf mortalities wolf predation consistently was the primary cause of death (66.7%), and bear predation was next (15.8%). Hiding cover was a dominant attribute at calving sites compared to pre-calving sites, whereas canopy closure and forage availability were greater at peak-lactation sites, indicating that balancing security and nutritional requirements influenced habitat selection over time.

Ratios of urinary urea nitrogen to creatinine ≥ 3.5 indicated more severe nutritional restriction during winters 2013, 2016, and 2017 compared to 2014 and 2015. Annual incidences of severe nutritional restriction were correlated with estimates of population size ($r = -0.863$), calf production ($r = -0.922$), and winter survival of adult moose ($r = -0.860$), indicating that winter undernutrition is playing a role in the poor population performance.

Our results will improve understanding of if, when, and how moose are able to successfully modulate their internal body temperature, which can inform strategies for conserving the population, especially through habitat management.

PROJECT RESULTS USE AND DISSEMINATION

For the moose research projects supported by this funding we have produced 8 peer-reviewed publications, 4 manuscripts currently in review, and several more to come with final analyses of the data. There have been 15 DNR agency reports written, and they are available from our wildlife publications website (<http://www.dnr.state.mn.us/publications/wildlife/index.html>). Agency staff and graduate students have given 117 presentations at professional conferences of all levels—state to international—other meetings with professional biologists, and to all manner of public audiences, from school groups to sporting and nature groups to a veterans group.

During these 3 years the lead investigators, Drs. DelGiudice and Carstensen, have participated in 38 interviews with journalists from television, radio, and print outlets, and there have been more than 175 additional instances of media coverage about our research. Media outlets included all major newspapers in Minnesota and 2 adjacent states, many smaller newspapers, the Washington Times, National Geographic, public and commercial radio stations in Minnesota, and public, network, and cable television stations in Minnesota.

Furthermore, we have posted information on our DNR moose research website (<http://www.dnr.state.mn.us/moose/index.html>) throughout the project, and our results will be used to inform public stakeholder groups and DNR decisions about moose conservation.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Expansion of Minnesota Wildflowers Online Botanical Reference

Subd. 05n \$150,000 TF

Katy Chayka

MN Wildflowers Information

1590 Long Lake Rd

New Brighton, MN 55112

Phone: (651) 399-4064

Email: info@minnesotawildflowers.info

Web: <http://www.minnesotawildflowers.info/>

Appropriation Language

\$150,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Minnesota Wildflowers Information to accelerate field work for surveying and imaging of plant species and publication of species profiles to 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 shall 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, 2017, by which time the project must be completed and final products delivered.

Project Overview

The average Minnesotan and even most natural resource managers are not skilled in plant identification, yet the ability to positively identify plants is crucial to a number of conservation activities, including identifying areas that need protection, recognizing new or existing invasive species, monitoring restoration projects, and delineating wetlands. The Minnesota Wildflowers project attempts to fill this need with a free web-based field guide ultimately aimed at providing profiles for each of the over 2,100 vascular plant species in Minnesota. Minnesota Wildflowers Information is using this appropriation to continue to update and expand the information contained on its online field guide by doubling the number of new species profiled. Information will be freely available to the public, students, and natural resource professionals as a learning reference and to assist in plant identification.

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 specific plants, photographing the identifying characteristics, describing each species 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 ENRTF 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 3-year funding period, the 2-member team traveled 35,000 miles visiting locations in 64 Minnesota counties, photographed 1200 plant species, 500 of which had not previously been photographed. This field work resulted in significantly increased coverage. As of June 30, 2017, 1337 species have been published (over 60% of all Minnesota plant species) including trees/shrubs, grass-like plants and ferns. More than 220 species profiles were updated with improved images and information. Traffic has more than doubled with over 5,000 visits and nearly 23,000 pages viewed per day during 2017 peak season. 468,000 unique users were served in 2016 and numbers continue rising. This clearly shows the website is a valued resource and the more species covered, the more valuable it becomes.

PROJECT RESULTS USE AND DISSEMINATION

While word-of-mouth and Google searches are the source of much traffic, our web statistics show the single highest usage comes 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. 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 partnered with the DNR State Parks and Trails on their wildflower geocaching program, were profiled in the Minnesota Conservation Volunteer magazine, and gave presentations about the project to the Minnesota Native Plant Society, the Minnesota Wetlands Professionals Association, the Minnesota Landscape Arboretum, Master Naturalists, Master Gardeners, Wild Ones and several garden clubs.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Subd. 06 Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Understanding Systemic Insecticides as Protection Strategy for Bees - RESEARCH

Subd. 06b \$326,000 TF

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

\$326,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to continue research on how native bee and honey bee colonies are impacted by systemic, neonicotinyl insecticides in pollen and nectar of plants growing in fields and landscapes. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

A class of insecticides known as systemic neonicotinyl insecticides has been identified as a potential factor in recently observed declines in pollinators, including the phenomenon amongst honeybees known as Colony Collapse Disorder. Previous research examining the effects of neonicotinyl insecticides on lab colonies of bumblebees found that exposure to these insecticides at various levels increased queen bee mortality and detrimentally altered bee behavior and production. Researchers at the University of Minnesota are using this appropriation to continue this research aimed at quantifying levels of insecticide residues in pollen and nectar of plants treated with systemic insecticides to determine how exposure to these residues affects bee colony health. This phase expands the research to conduct studies in the field in a natural setting.

OVERALL PROJECT OUTCOME AND RESULTS

Our objectives were to understand how to protect pollinators. We wanted to understand if bees were affected when feeding on pollen from ornamental plants that were treated with imidacloprid, a neonicotinoid insecticide. Neonicotinoids are systemic and are applied to the soil or injected into trees. Both native bees, *Bombus impatiens*, and managed bees, *Apis mellifera*, are affected in similar ways by imidacloprid. The imidacloprid dose in flower pollen that kills bees is 40 ppb and below 25 ppb imidacloprid causes sublethal effects on behavior.

Objective 1-1, 1-2, 1-3.. Determine imidacloprid residue in leaves, flowers, soil, and pollen from a soil drench and trunk injection.

We studied imidacloprid residue in linden trees, bee friendly flowers, blueberries, and greenhouse plants grown to be installed in the landscape. Also, we investigated the effects on the EPA NOEL or sub-lethal limit of imidacloprid (20 ppb) on bumblebee colony health in the field.

Our data showed that trunk injections of imidacloprid caused very high levels of imidacloprid in flowers and pollen that would kill foraging bees. Soil drenches produced lower amounts in flower that are below the EPA sublethal level. However, dogwoods growing under the trees to which a soil drench was applied contained sufficient imidacloprid residue to kill a foraging bee. These same flowers would not kill a house sparrow that fed on the dogwood berries. However, recent papers say these sublethal levels will affect bird movement and feeding. Bee friendly plants in landscapes did not accumulate enough residue after 1 application to kill a foraging bee. However, greenhouse applications to flowering baskets and pots resulted in sufficient residues to kill foraging bees.

Objective 2-1. Determine the impacts of these imidacloprid residues on colony health of native bumblebee.

A tier 3 EPA research field study with replicate plots was performed on the St Paul UM Campus. The bumblebee colonies were free flying and were fed 20 ppb imidacloprid in sugar syrup. The EPA NOEL (Not Effective Adverse Level or sub lethal dose) is 25 ppb imidacloprid. The bees in the treated colonies showed decreased movement, decreased sugar consumption, decreased brood, decreased queen production, and decreased hygienic behavior. Bumblebee colonies are negatively affected by 20 ppb imidacloprid. So the NOEL identified by the EPA in March 2016 as 25 ppb is incorrect.

Our residue data and our bumblebee study tells us that imidacloprid residue in flowers from a trunk injection or flowering plants growing under trees treated with soil drenches or greenhouse treated flowering plants would contain sufficient residue to kill or negatively affect native bumblebee colonies.

PROJECT RESULTS USE AND DISSEMINATION

Dissemination: Objective 1-4. Share the research results through outreach with talks, workshops, pollinator website, and interviews.

We talked to the public and other researchers about the effects of pesticides on bees, the data from this research, and what municipalities and consumers could do in their green space to conserve bees. We held 3 workshops at the MN Landscape Arboretum, produced 2 websites on native bee conservation, spoke about the research in 10 talks/yr, and gave over 6 interviews/yr to radio, television, and print media.

Imidacloprid residue in plant parts after a standard imidacloprid EPA approved label rate application

Species/application type	Applied	Leaves (ppb)	Soil (ppb)	Flowers (ppb)	Pollen (ppb)	Sub-Lethal <25 ppb	Lethal >40 ppb
--------------------------	---------	--------------	------------	---------------	--------------	--------------------	----------------

Ratio of imidacloprid in whole flowers to pollen

13 EPA docs submitted by industry					25% of residue in flowers		
Prairie petunia, Ruella humilis	300 mg			1,100	267		X
Yellow bells, Tecoma stans	300 mg			109	109		X

Landscape trees: Imidacloprid residue

Objective 1-1. Determine imidacloprid residue in pollen and nectar of basswood (linden) trees from a soil drench and trunk injection.

		Yr 1		Flowers	Pollen	Sub-Lethal	Lethal
		July	Aug				
Linden 20 in DBH, soil drench	48 g	Yr1 July: 727	July:15,430	34	9		X
		Aug: 1,023	Aug: 5,956	No flow	No flow		
		Yr2 July 706	Yr 2	81	20		X
		Aug: 429	July:1,634	No flow	No flow		
			Aug: 534				
Linden 8 in DBH, soil drench	14 g	July: 13,675	July: 290	34	9		X
		Aug: 25,250	Aug: 385	No flow	No flow		
Linden 8 in DBH, trunk injection	3 g	July: 848	July: 14	1,340	335		
		Aug: 36,283	Aug: 14	No flow	No flow		X

Landscape trees: Imidacloprid residue

Objective 1-2. Determine imidacloprid residue in native plants around imidacloprid-treated trees

Dogwoods under soil drench		July: 21,061	Aug: 16,787	762 Fruit: 425 will not kill house sparrows eating fruit	190		X
----------------------------	--	--------------	-------------	--	-----	--	---

Landscape Bee plants: Imidacloprid residue

Objective 1-3. Determine imidacloprid residue in pollen and nectar of native flowers and blueberry from imidacloprid soil drenches.

Agastace foeniculum, anise hyssop	25 g	561	94	24	X
Asclepias currassavica, tropical milkweed	25 g	132	87	22	X
Commercial blueberries Collaboration with Koppert			residue in 5/6 flower samples (220, 136, 42, 10, 12 ppb), mean 84 ppb	Bumblee bee colonies in these fields declined.	X

Greenhouse Bee plants: Imidacloprid residue

Objective 1-3. Determine if greenhouse grown plants in hanging baskets contained sufficient residue to harm foraging bees.

Prairie petunia, Ruella humilis	120 mg	July: 14,400 Aug: 2,086	July: 1,100 Aug: 502	July: 267 Aug: 126	X X
Million bells, Calibrachoa	200 mg	July: 67,266 Aug: 34,166	July: 1,972 Aug: 333	July: 615 Aug: 83	X X

Greenhouse Bee plants: Imidacloprid residue

Objective 1-3. Determine if greenhouse grown plants in pots contained sufficient residue to harm foraging bees.

Agastace foeniculum, anise hyssop	300 mg		1,973	493	X
Asclepias currassavica, tropical milkweed	300 mg		1,568	392	X
Yellow bells, Tecoma stans	300 mg		106	106	X
Canola	300 mg		4,144	1,036	X
Rose Consumer label	300 mg		1,175	293	X
Rose Greenhouse label	240 mg		812	203	X

Landscape experiment on bumblebees at 20 ppb imidacloprid below EPA NOEL of 25 ppb Objective 2-1.

Determine the impacts of these imidacloprid residues on colony health of native bumblebee.

Imidacloprid at the EPA sublethal rate of 20 ppb caused fewer queens to be produced, lower nest weight, and less hygienic behavior compared to controls.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Prairie Sustainability through Seed Storage, Beneficial Microbes, and Adaptation - RESEARCH

Subd. 06c \$600,000 TF

Ruth Shaw

U of MN

100 Ecology; 1987 Upper Buford Circle
Minneapolis, MN 55108

Phone: (612) 624-7206

Email: shawx016@umn.edu

Web: <http://www.cbs.umn.edu/explore/departments/eeb/faculty-research/directory/ruth-g-shaw>

Appropriation Language

\$600,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to collect and preserve germplasm of plants throughout Minnesota's prairie region, study the microbial effects that promote plant health, analyze local adaptation, and evaluate the adaptive capacity of prairie plant populations. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Healthy prairies contribute numerous benefits, such as providing habitat for wildlife and pollinators, maintaining and improving water quality, stabilizing roadsides, and providing a sustainable source of materials for bioenergy production and other products. Since European settlement the once vast expanses of Minnesota prairie covering 18 million acres have been reduced to small remnants totaling about 235,000 acres. With this decline has also come a drastic reduction in the genetic diversity of the various species typical of Minnesota prairies. This has resulted in inbreeding of remnant species populations, which reduces the robustness of plants and can result in yet further population decline. Researchers at the University of Minnesota are using this appropriation for efforts aimed at protecting the long-term health and sustainability of remaining prairie in the state by collecting prairie plant genetic material for long-term preservation, collecting and studying microbes that promote prairie plant health, and examining the capacity for prairie plants to adapt to changing conditions. Information and resources derived from this effort will contribute to improving restoration techniques and ensuring healthy prairies into the future.

OVERALL PROJECT OUTCOME AND RESULTS

The once vast MN prairie harboring tremendous genetic diversity has been drastically diminished. Society's increasing recognition of the multifarious benefits MN prairie provides has generated demand for scientifically based prairie conservation and restoration. Accordingly, this project undertook to:

- preserve seeds of 40 plant species from sites throughout MN's prairie region,
- identify microbes that promote prairie plant health,
- discover the scale of local adaptation for prairie plant species, and
- predict the rate of future adaptation of prairie plant populations.

Outcomes:

We obtained genetically representative collections from over 330 populations of 64 plant species native to MN prairie. To ensure lasting viability of these seeds, many are stored at the USDA National Center for Genetic Resources Preservation in Fort Collins, CO.

We characterized microbial communities on prairie plants, isolating and identifying over 2500 strains from prairie clover. Graduate student DeMers presented these findings at a national scientific meeting. We conducted an experiment to determine whether microbes benefit host plants that originate from the same site more than they benefit host plants from different sites; analysis is ongoing.

We established 3 field experiments to clarify the extent to which plants survive and reproduce more when they are planted near their site of origin. This study focuses on 6 prairie species, each sampled from 12 sites. Monitoring of survival and growth of plants is proceeding, as is analysis of this dataset.

To assess the genetic variation available to support adaptation, we established foundation plantings of little bluestem, in preparation for estimating the adaptive capacity of two populations.

PROJECT RESULTS USE AND DISSEMINATION

In accomplishing these goals, we have advanced:

1. Relationships with professional native-seed collectors and with several student groups at rural MN university campuses.
2. Scientific training of 10 undergraduates at 3 Minnesota university campuses, 7 technicians, 3 graduate students, and 2 post-doctoral associates and engagement of over 60 community volunteers and over 400 others.
3. Discussions with users and producers of native seed, aiming to increase source-identified seed available for prairie restorations in Minnesota.

This Project has expanded the diversity and volume of local, source-identified seeds and microbes from Minnesota prairies and has collected and analyzed data that will support restoration of MN prairie. All aspects of this project are being continued through new funding from the ENRTF.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Northeast Minnesota White Cedar Restoration - Phase 2

Subd. 06d \$335,000 TF

Dale Krystosek

Board of Water and Soil Resources

520 Lafayette Road N

Saint Paul, MN 55155

Phone: (218) 820-9381

Email: dale.krystosek@state.mn.us

Web: <http://www.bwsr.state.mn.us/>

Appropriation Language

\$335,000 the second year is from the trust fund to the Board of Water and Soil Resources to continue an assessment of the decline of northern white cedar plant communities in northeast Minnesota, demonstrate restoration techniques, and provide cedar restoration training to local units of government. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Northern white cedar wetland plant communities provide unique ecological, economic, and wetland functions, including high value timber, long-term carbon storage, winter refuge for deer and other wildlife, wildlife habitat, and thermal buffering for brook trout streams. However, these plant communities have been declining in Minnesota for decades mostly as a result of development impacts. The Minnesota Board of Water and Soil Resources is using this appropriation to continue efforts aimed at improving the quantity and quality of white cedar wetland plant communities in Minnesota. Efforts will include assessing existing white cedar communities to prioritize sites for restoration and then providing training and demonstration of restoration and re-vegetation techniques for local natural resource managers.

OVERALL PROJECT OUTCOME AND RESULTS

Project Background: Northern white cedar (*Thuja occidentalis*) has been declining in Minnesota for decades. White cedar provides ecologically diverse plant communities and critical wildlife habitat and wetland functions. (Phase 2).

Project Goals:

1. Reverse decline of white cedar plant communities in Minnesota.
2. Complete two hydrologic restorations of white cedar plant communities and develop recommendations for restorations.

Methods: Board of Water and Soil Resources (BWSR) established 2 white cedar hydrologic restorations in Itasca and Lake Counties. Engineering designs were developed to restore natural groundwater flows where forest roads had impacted white cedar stands. A training video was developed for land managers. Dr. Rod Chimner evaluated the effectiveness of the hydrologic restorations plus the phase 1 vegetative restorations of northern white cedar plant communities.

Results:

1. Hydrologic Restoration:
Goal: Restore 2 sites where roads had impacted white cedar plant communities.
Results: Two experimental methods of hydrologic restoration were completed in Itasca and Lake Counties.
2. Monitor seven phase one white cedar restoration sites:
Results: 7 sites established in Beltrami, Koochiching, St. Louis and Lake County were monitored.
3. Develop recommendations for white cedar restoration and evaluate additional sites:
Results:
 - o Recommendations for white cedar restoration were developed.
 - o 75 additional restoration sites were evaluated by SWCDs.
 - o Northern white cedar has limited ability to replace black ash stands due to high water levels.
 - o White cedar restoration video developed and disseminated.

Project Findings:

- e. Many white cedar swamps are degraded and need restoration.
- f. Major disturbances were roads, ditches and herbivory.
- g. After two years, the largest single factor affecting northern white cedar survival was hydrology.
- h. Light levels (shading) plays a role in cedar regeneration.
- i. After one season, the hydrologic restoration of two forest roads were successful, restoring hydrologic flow conditions.

Project Significance: Northern White cedar provides unique functions including:

- o Thermal winter cover for white tailed deer
- o Critical habitat for pine marten, bear, fish, songbirds
- o Provides thermal buffering for cold water fisheries (brook trout streams)

PROJECT RESULTS USE AND DISSEMINATION

Presentations were given at a scientific conference, to other various interested organizations and project stakeholders (Voyageurs National Park, MN DNR, MN DOT, St. Louis County Highway Department, Superior National Forest, U of M, NRRI, Michigan Tech). A 30 minute radio interview was conducted at KTWB, Two Harbors. Scheduled to present project results to the Minnesota Forest Resources Council and Forestry Committee in International Falls.

Collaboration with the Itasca Community Television (ICTV) to capture video and photography of all stages of construction of hydrologic construction sites. Footage has been edited and training videos have been created. The videos have been distributed to multiple stakeholders, including BWSR, DNR, MPCA and County Forestry Offices, U of M and Federal Agencies. Videos will be made available on the BWSR web page (<https://spaces.hightail.com/space/wYWZBy450n>).

Work with staff from the Superior National Forest to set up field reviews of potential sites that the Forest Service would like to restore hydrology and white cedar plant communities, by utilizing this project's findings. Work is continuing in reaching out to foresters from County Land and Forestry Departments, DNR Foresters, U.S. Forest Service to build avenues for disseminating project findings and generate interest in for white cedar restoration.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Northeast Minnesota White Cedar Plant Community Restoration: Phase I & II Technical Report](#)

Southeast Minnesota Watershed Protection Plan Subd. 06e \$200,000 TF

Richard Biske

The Nature Conservancy
PO Box 405
Preston, MN 55965

Phone: (507) 765-2450

Email: rbiske@tnc.org

Web: <http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/minnesota/>

Appropriation Language

\$200,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with The Nature Conservancy to provide a framework and plans for the protection and stewardship of unimpaired waters in southeast Minnesota. The result will be a template for watershed protection in Minnesota. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Often times water conservation efforts are directed toward impaired waters. However, it is much more cost-effective to protect habitat and water resources before they become degraded. The Nature Conservancy is using this appropriation to create a broader, long-term, watershed-based framework for proactively protecting habitat and water resources in southeast MN, specifically the Cannon River and Zumbro River watersheds, before they become degraded. Information will help guide efforts for assessing and prioritizing conservation efforts in southeast MN and provide a framework for other watersheds in the state to replicate.

OVERALL PROJECT OUTCOME AND RESULTS

Despite extensive watershed planning in Minnesota, much of the efforts to date have focused on the restoration of impaired waters. Many watersheds in Minnesota have relatively healthy, unimpaired minor watersheds or sub-watersheds. These watersheds often have considerable private ownership with upland habitat, perennial vegetation or compatible land use that is resulting in clean, unimpaired waters. Yet, these landowners with existing habitat on their properties can be overlooked for conservation assistance for water quality purposes. This project completed healthy watershed plans or Landscape Stewardship Plans (LSPs) for the Cannon and Zumbro Rivers in Southeastern Minnesota. The LSPs for the watersheds included several GIS analyses identifying ecosystem services of natural communities and priority habitat complexes within a watershed context. This information was used to prioritize Conservation Opportunity Areas (COAs) within each watershed. The plans identified a combined 589,396 priority acres out of 1,849,500 acres studied across 11 COAs encompassing minor watersheds. Four COAs were selected within the Cannon River covering 277,196 acres or roughly 30% of the watershed. Seven smaller COAs were identified within the Zumbro River watershed covering 312,200 acres or 34% of the watershed. These COAs provide guidance on protecting and restoring the most important watersheds and identified properties within them to meet multiple watershed conservation goals including water quality, upland and aquatic habitat and recreation.

The project resulted in 20 property-wide stewardship plans covering 3,000 acres listing a range of management practices for unique zones on each property. In addition to the stewardship plans 20 Conservation Action Plans (CAP) for 168 acres were developed. The CAPs can be used to apply for and implement state and federal cost-share programs for activities like prescribed fire, invasive species control and tree thinning for forest stand improvement. The 2014 Clean Water Accountability Act and subsequent Nonpoint Funding Prioritization Plan directed state agencies to target restoration activities to those impaired waters that are closest to meeting Minnesota water quality standards and to protect those high - quality unimpaired waters at greatest risk of becoming impaired. The

watershed planning approach utilized in this project prioritizes functional landscapes for healthy watershed protection as an important component to the Watershed Restoration and Protection Strategies and One Water One Plans developed by state and local partnerships. To date watershed planning has focused on the more costly aspect of restoring highly degraded waters, not those in need of protection to prevent impairment. By focusing limited technical and financial resources on intact functional landscapes and the clean waters they support, costly restoration can be avoided and ecosystem services can be maintained. This project provides an actionable plan for the Cannon and Zumbro Rivers and a process for other watersheds to achieve the goals of the Clean Water Accountability Act and Nonpoint Funding Prioritization Plan.

PROJECT RESULTS USE AND DISSEMINATION

Plans along with supplemental materials have been prepared to disseminate the most important content of the LSPs to relevant stakeholders and conservation planners. Landscape Stewardship Planning is being recognized as a valuable resource in watershed based plans in SE Minnesota, including the Cannon and Zumbro Watersheds. Both LSPs have been incorporated by reference into the corresponding Watershed Restoration and Protections Strategies (WRAPS) documents for the Cannon and Zumbro Watersheds. The Cannon River Watershed is now beginning the process of adopting a One Watershed One Plan (1W1P), and the technical committee has already been given a presentation on the LSP. The contributions of key partners and stakeholders in developing the plans will also increase their dissemination, as future partners recognize their own contributions and “buy in” to the process.

While the LSPs themselves are targeted at a more technical audience for use in conservation planning, the goals and themes of good stewardship of natural communities for watershed protection have been distributed to a general audience through landowner field days held in the Cannon River Watershed.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Landscape Stewardship Planning Document](#)

[Brochure - Cannon River Watershed](#)

[Overview - Cannon River Watershed](#)

[Landscape Stewardship Plan - Cannon River Watershed](#)

[Brochure - Zumbro River Watershed](#)

[Overview - Zumbro River Watershed](#)

[Landscape Stewardship Plan - Zumbro River Watershed](#)

Upland and Shoreline Restoration in Greater Metropolitan Area

Subd. 06f \$300,000 TF

Wiley Buck

Great River Greening
35 W Water St, Ste 201
St Paul, MN 55107

Phone: (651) 665-9500

Email: wbuck@greatrivergreening.org

Web: <http://www.greatrivergreening.org>

Appropriation Language

\$300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Great River Greening to restore and enhance upland, shoreline, and approximately 150 acres of forests, woodlands, savanna, and prairie and to provide related educational opportunities for volunteers in the greater metropolitan area. A list of proposed restorations and enhancements must be provided as part of the required

work plan. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Though many parts of the Twin Cities metropolitan area are urbanized, there are also has large areas of natural lands that continue to serve as important habitat for fish, wildlife, and plant communities. However, pressure on these remaining lands continues to intensify as population and development pressures increase. This appropriation continues the efforts of the Metro Conservation Corridors (MeCC) partnership, an ongoing effort by a partnership of state and non-profit organizations, to conduct strategic and coordinated land conservation activities that build connections between remaining high quality natural areas in the greater Twin Cities metropolitan area and ensures their benefits are available for future generations. Great River Greening is using this appropriation to restore approximately 150 acres of permanently protected forest, woodland, savanna, and prairie habitat while engaging hundreds of volunteers in the stewardship of the metropolitan area's remaining natural areas.

OVERALL PROJECT OUTCOME AND RESULTS

Along with partners and volunteers, Great River Greening completed twelve restoration projects to reduce habitat fragmentation, enhance habitat quality, and reconnect habitat corridors. With Trust Funds and leveraged matching funds, Greening conducted restoration and enhancement efforts on ecological corridors and ecological cores on 291 acres of prairie, oak savanna, woodland, wetland, and riparian habitats. In addition, Great River Greening created community connections, engaging and educating a total of 892 volunteers at five project sites. At these restoration events, volunteers performed habitat restoration techniques, participated in a roving presentation by an ecologist, learned about the larger restoration process at the site, and gained insight on how to transfer knowledge gained to a project at home or in their local community.

Great River Greening produced the following results:

1. Completed a management plan for Westwood Hills Nature Center (WHNC) in St. Louis Park, to “enhance the diversity and resilience of the plant communities at WHNC to increase their value as both wildlife habitat and to enhance their utility as outdoor classrooms.”
2. Restored/enhanced 135.5 acres of upland habitat with Trust Funds (target = 147 acres), which included 0.6 miles of shoreline (target = 0.26 miles), at an average cost of \$1902 per acre. Restored/enhanced an additional 155.5 acres with leveraged matching funds for a total of 291 acres of habitat restored/enhanced (target = 247 acres).
3. Engaged 892 volunteers in meaningful restoration projects with environmental education from Greening ecologists (target = 300 volunteers). 294 of 892 volunteers were youth, age 17 or under.
4. Leveraged \$114,885 in non-state funds and \$189,419 in state funds, for a total of \$304,304 leveraged matching funds for habitat restoration/enhancement, volunteer events, and management plan development.

Summary Table: Trust Fund Deliverables by Parcel

Parcel Name	City	County	Habitat Acres	Shoreline miles	Volunteers
Katherine Abbott Park Phase II	Mahtomedi	Washington	10	0.0	106
Carver Park Reserve	Victoria	Carver	16	0.0	51
Allemansratt Park Phases I, II, III	Lindstrom	Chisago	23	0.0	0
Trout Brook Nature Preserve Phase II	St. Paul	Ramsey	2	0.0	524
Lilydale Bluffs	St. Paul	Ramsey	0	0.0	0
Accelerated Migration Technique	Cottage Grove	Washington	3	0.0	0

Prescribed Grazing/Haying, at a) Central Corridor b) Pilot Knob Hill	a) Cottage Grove b) Mendota Heights	a) Washington b) Dakota	34	0.0	63
Westwood Hills Nature Center Phase I, II	St. Louis Park	Hennepin	25	0.1	148
Wolsfeld Woods SNA	Long Lake	Hennepin	11	0.5	0
Dodge Nature Center II	West St. Paul	Dakota	8	0.0	0
Bur Oak Research: Central Corridor, Allemansrätt Park, Otter Lake, Fish Creek Open Space	Cottage Grove, Maplewood, Lindstrom, White Bear Lake	Chisago, Ramsey, Washington	3	0.0	0
Fish Creek Open Space	Maplewood	Ramsey	0.5	0.0	0
TOTALS			135.5	0.6	892

PROJECT RESULTS USE AND DISSEMINATION

Greening is in active partnership with landowners, other land managers, service providers, conservation peers, and volunteers resulting in a dynamic and timely exchange of information and results.

Volunteer event descriptions acknowledging Trust Fund contributions and qualitative results were emailed to Greening's e-subscribers in July 2014, February 2015, July 2015, spring 2016, fall 2016 and spring 2017 in advance of spring and fall volunteer event seasons; over the course of the grant, the number of subscribers increased from approximately 5,000 to over 8,500. Information about Metro Conservation Corridors is on the Great River Greening website at <https://www.greatrivergreening.org/category/mccorridor/>; over the course of the grant, visits to the website increased from 1,100 to over 1,500 visits per month. In addition, Greening's Facebook and Twitter pages have featured the Pilot Knob Grazing Monitoring project, the Accelerated Migration/ White Oak Ecotype Study at Central Corridor, Allemansratt Wilderness Park, Trout Brook, Westwood Hills, and Carver Park. In March 2017, 150 attendees convened to attend The Best Practices for Pollinators in the Real World Summit, for Minnesota Counties, Municipalities, Leaders. During the conference, Washington County Parks presented on Innovative Management Approaches, highlighting the South Washington conservation haying project. In addition, five press articles from the Pioneer Press, Star Tribune, and Lillie News disseminated information about Pilot Knob Hill, publicizing its addition to the National Register of Historic Places and the prescribed grazing project.

Project Completed: 06/30/2017

[FINAL REPORT](#)

**Prairie, Forest, and Savanna Restoration in Greater Metropolitan Area
Subd. 06g \$200,000 TF**

Tom Lewanski

Friends of the Mississippi River
101 East 5th St, Suite 2000
St Paul, MN 55101

Phone: (651) 222-2193 x12

Email: tlewanski@fmr.org

Web: <http://www.fmr.org>

Appropriation Language

\$200,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Friends of the Mississippi River to restore approximately 150 acres of prairie, forests, and oak savanna in the greater metropolitan area. A list of proposed restorations and enhancements must be provided as part of the required work plan. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Though many parts of the Twin Cities metropolitan area are urbanized, there are also has large areas of natural lands that continue to serve as important habitat for fish, wildlife, and plant communities. However, pressure on these remaining lands continues to intensify as population and development pressures increase. This appropriation continues the efforts of the Metro Conservation Corridors (MeCC) partnership, an ongoing effort by a partnership of state and non-profit organizations, to conduct strategic and coordinated land conservation activities that build connections between remaining high quality natural areas in the greater Twin Cities metropolitan area and ensures their benefits are available for future generations. Friends of the Mississippi River is using this appropriation to restore approximately 150 acres of permanently protected prairie, forest, and oak savanna habitat in the metropolitan area.

OVERALL PROJECT OUTCOME AND RESULTS

Friends of the Mississippi River worked to enhance 150 acres of prairie and 82.5 acres of woodland for a total of 232.5 acres at six properties in the Twin Cities metropolitan area: Hastings Sand Coulee Scientific and Natural Area (SNA), Orvin Ole Olson Park in Minneapolis, Pine Bend Bluffs Natural Area in Rosemount, a Ravenna Township conservation easement property, River Oaks Park in Cottage Grove and Rosemount Wildlife Preserve. We enhanced an additional 46 acres of prairie and 44.5 acres of woodland using non-state match. All of the project sites are within the designated Metro Conservation Corridors, a planning tool that shows connectivity among parks and natural areas.

All management activities were based on an established Natural Resource Management Plan for the site. Each of the projects were directed at improving the ecological health and wildlife value of the site by improving the abundance and diversity of native plant species. All of the sites were degraded by non-native plants that displaced the native plants and the wildlife that depend on them. Restoration techniques and activities included prescribed burning, control and eradication of non-native invasive plant species, native woody plant removal from prairies, seed collection, and seeding and plant installation. Such practices increase the resilience of the native plant community so that it can better sustain itself and provide better wildlife habitat. This project also enabled matching funds to be used to engage dozens of volunteers in these restoration efforts.

PROJECT RESULTS USE AND DISSEMINATION

FMR disseminated information about the project sites and the ENRTF primarily through two means. We published a couple of short articles about stewardship events at our project sites in our electronic newsletter that included information about ENRTF. In addition, during volunteer events, FMR discussed the project and the source of funding. The Environment and Natural Resources Trust Fund was also named as a funder in FMR's 2016 annual report.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Nutrient Capture Through Water Management and Biomass Harvesting
Subd. 06h \$300,000 TF

Leah Thvedt

Red River Basin Commission

1120 28th Ave N, Suite C
Fargo, ND 58102

Phone: (701) 356-3183

Email: leah@redriverbasincommission.org

Web: <http://www.redriverbasincommission.org>

Appropriation Language

\$300,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Red River Basin Commission to evaluate the potential capture of excess nutrients using cattails grown and harvested within shallow flood reservoirs for bioenergy use. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Excess nutrients are among the most common impairments of water resources in the Red River Basin, as well as the rest of Minnesota. About 80% of the land use in the Red River Basin is for agricultural cropland and over 90% of phosphorus and nitrogen found in rivers and streams in the area originate from nonpoint sources, such as cropland. Excess nutrients are also one of the most difficult impairments to correct. The Red River Basin Commission is attempting to help correct this problem by using this appropriation to develop and evaluate an innovative, multipurpose method to use cattails and other vegetation within existing flood storage reservoirs to capture and reduce nutrient loads from runoff originating from mostly non-point sources and then use the harvested vegetation for purposes including bioenergy production and fertilizer. If effective this technique could be implemented in multiple locations in the Red River Basin and in other agricultural regions of the state to assist in reducing nutrient loads in waterways.

OVERALL PROJECT OUTCOME AND RESULTS

This project evaluated the potential for capturing nutrient runoff from nonpoint sources by utilizing cattails or other vegetation within existing shallow flood storage reservoirs. Utilizing the North Ottawa (NO) Project in the Bois de Sioux Watershed District(BDS). Over 80% of the phosphorus and nitrogen (nutrient) loads that are being discharged downstream are coming from nonpoint runoff mostly from agricultural fields. This project developed and evaluated a new methodology for capturing and reducing the nutrient loads coming off agricultural dominated watersheds. This technique provides a new and effective "tool" for addressing nutrient reductions. The project provides water quality improvements downstream of the impoundment which is then passed on to the rivers and streams of this project including the Red River. As the desire for reductions in phosphorus and nitrogen have led to increased regulation in the state of Minnesota these types of projects will only assist in meeting these regulations and offering another layer of reduction. The data that has been collected is submitted to EQUIS. The desired outcome is to capture and remove 50- 100 percent of the phosphorus and nitrogen nutrients found in surface drainage water from the 75 square mile agricultural watershed above the North Ottawa flood impoundment. The interior dikes were constructed for the management of water within the 1920 acre impoundment in 160 acre treatment cells. The four-160 acre Pool B cells will give us the ability to hold water for differing time periods and to manage vegetation differently within these cells to maximize nutrient capture. In 2016, the RRBC harvested cattail biomass from the NO Impoundment and utilized the harvested material as a green manure on agricultural land within the upstream drainage area. Using conventional forage chopping equipment resulted in a 4.76 tons per acre biomass yield. Nutrient analysis of the harvested biomass equated to 48 lbs. nitrogen and 6.6 lbs. phosphorus captured per acre harvested (10 acres) resulting in 480 lbs of Nitrogen and 66 lbs of Phosphorus removed from the system . By scaling up the harvesting, capture and removal of 50 - 100 percent of the phosphorus and nitrogen nutrients is feasible.

Ongoing monitoring is critical to and allows an accurate determination of when nutrients are entering the impoundment and how to manage water levels to optimize water quality benefits. Management strategies included drawdown timing and velocity, water retention time for settling nutrients, and optimizing vegetation for nutrient reduction.

PROJECT RESULTS USE AND DISSEMINATION

The goals and outcomes of this project continue to be presented and shared at most events in the Red River Basin. The RRBC is presently working closely with the Bois de Sioux Watershed District Managers and Administrative staff to provide all the information and outcomes from the work being done at their North Ottawa Impoundment. The BDS has established a project team specific to this effort to look at future tasks and work that could be evaluated at the impoundment site.

The marketing materials, handouts and videos produced will be distributed as a part of our larger basin outreach strategy. These materials will also be showcased at our upcoming Ex Officio board meeting and annual conferences. The final documents will also be posted on our website. Manitoba is also doing research with cattail bio mass and nutrient reduction but on a much smaller scale than North Ottawa. They are extremely interested in the results and continued data that will come out of this project. The RRBC and our partners have done more than 5 tours of North Ottawa since the beginning of this project in 2014.

RRBC Staff have presented too many entities as part of the RRBC's larger outreach strategy around the basin about this effort and conclusions and recommendations for the future. We are diligently working to communicate the excellent data that has come out of this effort to other entities to garner future financial support to continue monitoring for the foreseeable future. This would allow an opportunity to understand the system and the uncontrollable variables that impact the functioning of this impoundment and how that translates into water quality benefits. It will also speak to the longevity of these types of projects and the life of nutrient capture in impoundments. We will be able to use this information and apply to projects of this nature and hopefully one day be provide quantitative data in proposed retention/detention project cost benefit ratios.

Project Completed: 06/30/2018

[FINAL REPORT](#)

[Cattail Nutrient Removal: Handout](#)

[Feeding Green Cattails: Handout](#)

[Harvesting Cattails: Handout](#)

Subd. 07 Land Acquisition, Habitat, and Recreation

Scientific and Natural Area Acquisition, Restoration, Improvement and Citizen Engagement

Subd. 07a \$2,540,000 TF

Peggy Booth

MN DNR

500 Lafayette Rd, Box 25

St. Paul, MN 55155

Phone: (651) 259-5088

Email: peggy.booth@state.mn.us

Web: <http://www.dnr.state.mn.us/snas/index.html>

Appropriation Language

\$2,540,000 the second year is from the trust fund to the commissioner of natural resources to acquire 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 parts 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 program. 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, 2017, by which time the project must be completed and final products delivered.

Project Overview

Minnesota's Scientific and Natural Areas (SNA) Program is an effort to preserve and perpetuate the state's ecological diversity and ensure that no single rare feature is lost from any region of the state. This includes landforms, fossil remains, plant and animal communities, rare and endangered species, and other unique biotic or geological features. These sites play an important role in scientific study, public education, and outdoor recreation. The Minnesota Department of Natural Resources is using this appropriation to permanently protect approximately 240 acres of high quality habitat with rare species and unique natural resources of statewide significance; to restore approximately 770 acres of existing SNAs to conserve the rare features they protect; and to monitor existing SNAs to gauge, improve, and verify that site specific conservation values are protected and achieved. The project includes engagement activities for local communities to help build a network of people to be involved with their local SNAs.

OVERALL PROJECT OUTCOME AND RESULTS

Four parcels totaling 395 acres (238 acres pro-rated to this appropriation) were acquired and designated as SNA: two parcels totaling 286 acres (225 prorated acres) became the new **Brownsville Bluff SNA** (Houston Co); 37 acre (10 prorated acres) new **Crystal Spring SNA** (Washington Co); and 72 acre (4 pro-rated acres) new **Lawrence Creek SNA** (Chisago Co).

Habitat restoration and enhancement project activities on over 1100 acres were completed including: construction of a 31-acre deer enclosure for a woodland restoration project; invasive species treatment on 442 acres at 46 SNAs; prescribed burns on 687 acres at 14 SNAs and prescribed haying on 120 acres at 2 SNAs; and site development work at 38 SNAs, plus new interpretive signs for 8 SNAs. Adaptive Management Plans were written for 9 SNAs and staff collaborated on 9 partner-led projects. Ecological inventory/monitoring of key species/features was completed on 16 SNAs to inform or evaluate restoration and enhancement projects. The SNA Facebook page achieved over 4,150 page likes. The SNA Flickr social media channel was launched with 42 members sharing over 675 high quality photos. Nature Notes e-newsletter was delivered to over 3,900 subscribers. Improvements to the SNA webpage included improved usability on mobile device, fully revised and Visiting Guidelines section of the SNA webpage and new/enhanced site descriptions. A series of three native lady's-slippers posters were developed (2000 each) and distributed to promote SNAs and Minnesota's native wildflowers. About 180 educational and natural resource management events were held involving over 1670 people. One or more volunteer site stewards help monitor and care for 131 SNAs (79% of SNAs – with a total of 165 site stewards). Regular communications are made with the stewards and SNA staff have provided site stewards (and other volunteers) with personal protective equipment to use during SNA events.

PROJECT RESULTS USE AND DISSEMINATION

The SNA program uses multiple media to engage the people of Minnesota in SNAs and to inform them about work done with support from ENRTF. The extent of outreach supported by this appropriation include the following. The SNA Facebook (<https://www.facebook.com/MinnesotaSNAs>) page has achieved over 4,150 page likes by June 2017. The SNA Flickr (https://www.flickr.com/groups/minnesota_snas/) social media channel was launched in February 2015; the site allows high quality photo sharing and with 42 members sharing over 675 photos. The 16th (Winter 2015) issue of the Nature Notes e-newsletter (<http://www.dnr.state.mn.us/snas/enews.html>) was delivered to over 3,900 subscribers. Improvements to the SNA webpage (<http://www.dnr.state.mn.us/snas/index.html>) include conversion of slideshows for each site from Flash to Javascript in order to improve usability on mobile device and the Visiting Guidelines section of the SNA webpage was fully revised and new/enhanced site descriptions have been written. Acquisitions acquired with this ENRTF appropriation are also featured on the website: Brownsville Bluff (<http://www.dnr.state.mn.us/snas/detail.html?id=sna02067>), Crystal Spring (<http://www.dnr.state.mn.us/snas/detail.html?id=sna02068>), and Lawrence Creek (<http://www.dnr.state.mn.us/snas/detail.html?id=sna02065>). A series of three native lady's-slippers posters were designed, printed (2000 each), and mostly distributed in order to promote SNAs ("Visit the Wild Places") and Minnesota's native wildflowers. Data and feedback were obtained from people seeking the first released copies of the 1st poster.

Project Completed: 06/30/2017

FINAL REPORT

Martin County Park and Natural Area Acquisition

Subd. 07e \$435,000 TF

Rich Perrine

Fox Lake Conservation League, Inc.

P. O. Box 212

Sherburn, MN 56171

Phone: (507) 235-6661, ext. 3

Email: richard.perrine@mn.nacdnet.net

Web: <http://foxlakeconservation.com/>

Appropriation Language

\$435,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the Fox Lake Conservation League, Inc. and Martin County to acquire approximately 40 acres in Martin County, including a ten-acre prairie remnant to be owned and managed by Martin County as part of its park system. A vegetation management plan must be developed and implemented and public access must be provided to the native prairie remnant. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

After years of discussions, some of the most diverse riparian, mesic, and dry hillside native prairie containing the only identified remnant population of Prairie Bush Clover in Martin County is available for permanent protection. Martin County is using this appropriation to acquire and permanently protect approximately 40 acres, including 10 acres of remnant prairie. The land will be turned into a county park providing recreational opportunities for local residents and educational opportunities for area students.

OVERALL PROJECT OUTCOME AND RESULTS

The primary goal of this project was to permanently protect Martin County's only known Prairie Bush Clover population, the ten-acre prairie remnant and a thirty-acre buffer. Adding this piece of native prairie habitat to the Perch Lake, Timberlane, Bright Lake and Cedar-Hanson County Parks which include native riparian forest habitats seemed the best way to protect it.

After a failed attempt to enroll the prairie remnant in the Prairie Bank program, several years went by before the landowner decided he may be willing to sell it as land prices rose to record highs. His asking price was four hundred thousand dollars for the forty that held the prairie remnant. He stated, "it is hilly, but grows good crops," and nearby cropland had just sold for 20% more than he was asking. So, we put together an application to the LCCMR outlining the value of probably the highest quality dry hillside and mesic prairie remnant remaining in Martin County, pointing out its proximity to the Martin County West School in Trimont, its value to students and the public. Wind energy generating towers were claiming similar positions on nearby hilltops.

Since starting to work with the landowner, new requirements that capped the amount that could be paid per acre for land acquisitions, appraisal requirements, a landowner request for payments to be made over three years, requiring a one-year project extension, were issues that delayed progress but were overcome.

A prairie plan was developed which includes a vegetation management plan and an infrastructure plan. An access, parking area and approximately 1,700 feet of trail were installed. Mechanical and chemical invasive species removal continues and prairie restoration work including weed control has been done and will continue for several years as the prairie remnant buffer is expanded. Handicap parking is adjacent to and at the same level as the trail. To benefit all Minnesotans, the entire trail up to and including the overlook is expected to be handicap accessible.

Once transplants and seeded plants become established in the clump plantings adjacent to the trail, signage will be installed to identify plant species. Our project suggests that we protect and buffer the best!

PROJECT RESULTS USE AND DISSEMINATION

The Martin County Park Board provided project leadership throughout the grant period, at monthly meetings, visited the site several times, and reported to the County Board and the community. The FLCL Board discussed priorities and project progress at monthly meetings and provided information to the public. The Martin SWCD featured the project with articles and photos, in the January and June editions of the "Conservation Update" and talked about the project on their weekly radio program throughout the grant period and offered visits to the site for "First Rite of Spring" celebrations as well as at other times of the year. Project information was offered at other public meetings, including the County Board, Martin SWCD, Water Plan Advisory Committee, and Martin County Conservation Club. Many photos of the site are available. Check the Martin SWCD website: www.martinswcd.net and the FLCL website: www.foxlakeconservation.com

Project Completed: 06/30/2018 [Extended in M.L. 2016, Chapter 186]

[FINAL REPORT](#)

Minnesota River Water Trailhead and Landing in Morton
Subd. 07f \$198,000 TF

Ted L. Suss

City of Morton

PO Box 127

Morton, MN 56270

Phone: (507) 828-3377

Email: tedsuss@gmail.com

Web: <http://www.mortonmn.com>

Appropriation Language

\$198,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the city of Morton to transform a municipal parcel from a compost site into a Minnesota River water trailhead and landing and to design and build interpretative trails around the landing complex. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Morton, Minnesota is home to many unique natural, cultural, and historic sites, including sites from the US-Dakota War and some of the oldest exposed rock, called Morton Gneiss, on the planet. The City of Morton is using this appropriation to develop a municipal site along the Minnesota River in Morton to be converted into a public canoe landing and campground and a trail connection between the Minnesota River State Water Trail and natural and cultural sites in the area including the Morton Outcrop Scientific and Natural Area. The project will provide increased recreational opportunities and amenities for users and provide a natural classroom for students to learn about the river.

OVERALL PROJECT OUTCOME AND RESULTS

The Charles Eastman Canoe Landing in Morton Minnesota, located on the Minnesota River has been completed. The project began with the removal of buckthorn and other invasive species on the entire site by a Conservation Corp of Minnesota work crew.

A picnic shelter/outdoor classroom was constructed on the rock outcropping overlooking the river. In order to make this portion of the project fully accessible, a new road was constructed from the existing city street, a dedicated parking area was paved, and a bathroom area and a sidewalk to the shelter was constructed.

Several large granite blocks, mined in Morton, were moved to the site and arranged to create an amphitheater classroom.

Three primitive campsites, each with a crushed granite base and a fire ring, were constructed. Trails, internal to the site, interconnect the canoe loading/unloading area with the canoe landing ramp, to the campsites, and to the shelter/classroom were constructed.

A cement plank canoe landing was installed on the riverbank.

A parking area was constructed.

The parking area, the trails connecting the parking area to the shelter, the camping sites, and to the river landing site were constructed by removing invasive plants and putting down a layer of crushed granite, a vegetation barrier, and an additional layer of crushed granite.

Interpretative, informational, and directional signage was designed, created, and installed. This signage includes a sign, conforming to Minnesota Historical Society standards for markers, that describes the life of Charles Eastman. An important element of the signage is a tasteful but prominent sign, visible from the river, announcing the landing site to paddlers.

This entire project was designed and completed not only to provide a canoe landing and trailhead, but to serve as a model for other communities along the Minnesota River State Water Trail as to how those communities can create a welcoming landing and wayside for paddlers and other recreational users of the Minnesota River.

PROJECT RESULTS USE AND DISSEMINATION

The public has been informed of this project through local news media including coverage of a well-attended dedication event in September of 2016. Speakers at this event included the Chairman of the Lower Sioux Tribal Community, the Regional DNR Supervisor, and a member of the LCCMR.

The Minnesota Department of Natural Resources has been formally asked to include this landing, trailhead, and campsite on the official Minnesota State Water Trail maps for this section of the Minnesota River.

A two-county tourism promotion organization, the Tatanka Bluffs Corridor Committee, has been asked and will feature pictures of the trailhead site in its upcoming 2017 visitors guide.

The Morton Chamber of Commerce has included promotion of the site on its web site/Facebook page. All dissemination efforts, including the main entrance sign, prominently cite the Environment and Natural Resources Trust Fund and the LCCMR as the source of funding to complete this project.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Subd. 08 Air Quality, Climate Change, and Renewable Energy

Solar Cell Materials from Sulfur and Common Metals - RESEARCH

Subd. 08a \$494,000 TF

Lee Penn and Eray Aydil

U of MN

207 Pleasant St SE

Minneapolis, MN 55455

Phone: (612) 626-4680

Email: rleepenn@umn.edu

Web: <http://www.chem.umn.edu/groups/penn/>

Appropriation Language

\$494,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop solar cell materials using nontoxic and common metals combined with sulfur. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Sustainable energy production is a major challenge facing our society. Solar energy is renewable and is a viable and attractive option. However, there are obstacles to widespread use. Current technology is expensive, making it difficult for businesses and homeowners to implement, and solar cells are commonly made using toxic and rare elements or using processes that require large amounts of energy. To become commonplace, solar cells must be inexpensive and robust, and they must be made of abundant, cheap, nontoxic materials. Researchers at the University of Minnesota are using this appropriation to develop and test an innovative, more energy and time-efficient method for producing thin film solar cells made of sulfur and common metals instead of the more toxic and rare elements currently used in most cases.

OVERALL PROJECT OUTCOME AND RESULTS

We successfully synthesized the proposed transition metal sulfide materials with controlled composition. Preparing materials without impurities, which essential for success since impurities in the thin film of light absorbing material will cause solar cells to fail, was particularly challenging. We identified which synthetic variables are most important for preventing impurities. In addition, we can successfully control particle size, which is important for making high quality thin films of these materials. We developed a reproducible protocol for preparing thin films of the particles. We examined effects of annealing conditions (sulfur partial pressure, heating rate, heating time, pre-annealing compaction, the nature of the molybdenum layer beneath the CZTS particles, and more) on the CZTS films and were able to identify ideal conditions for the necessary annealing step. A particularly exciting outcome was the development of a protocol for removing impurities from the thin films. During the annealing step, impurities often form even when the thin films are prepared using pure material. To solve this problem, we developed a selective etching method that effectively removes those impurities ("Selective Etching of Light Absorber Substrates", Application No. 62/328,851, which was filed April 28, 2016 but did not proceed to patent status).

Our biggest outcome expected was a fundamental advance in our ability to make high quality thin films of photovoltaic quality CZTS, and we did succeed in that regard. High quality thin films are required for the fabrication of high performing solar cells. In addition, we developed a green synthetic method for the controlled production of CZTS nanoparticles and can prepare high quality, microcrystalline thin films on conductive substrates using the microwave synthesis method. Unfortunately, we did not realize our final goal, which was to make a prototype solar cell fabricated using the aforementioned materials.

PROJECT RESULTS USE AND DISSEMINATION

We have published three papers in the peer-reviewed literature describing our results and two additional papers that are currently in review with scientific journals.

Unfortunately, Application No. 62/328,851, which was filed April 28, 2016, did not proceed to patent status. Our technology would have been used in the production of both copper indium gallium disulfide (CIGS) and copper zinc tin sulfide (CZTS) thin film solar cells. The changing solar cell market landscape and continued significant dominance of silicon solar cells over CIGS and CZTS devalued our technology despite its green advantages. Silicon solar cells now dominate over 90% of the solar cell market. Moreover, the provisional patent application was returned with objections and to narrow the claims. Continuing the patent application for these reasons did not make economic sense.

Project Completed: 06/30/2017

FINAL REPORT

Synthesis of nanocrystals and formation of polycrystalline: Publication
Controlling (CZTS) phase in micromave solvothermal synthesis: Publication
Chemically Deposited CdS Buffer: Publication

Innovative Groundwater-Enhanced Geothermal Heat Pump Study
Subd. 08b \$196,000 TF

Jimmy Randolph & Martin Saar

U of MN

116 Church Street SE

John T. Tate Hall Room 160

Minneapolis, MN 55455

Phone: (952) 457 8959

Email: rando035@umn.edu

Web:

Appropriation Language

\$196,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to analyze and validate a new geothermal pump method and technology that will reduce heat pump costs and improve performance and predictability. This appropriation is subject to Minnesota Statutes, section 116P.10.

Project Overview

Space and water heating and cooling consume 48% of all energy used in an average U.S. residence, and usually that energy is supplied by natural gas or fossil-fuel derived electricity. Geothermal heat pumps can reduce energy requirements for heating and cooling by up to 75%. However, traditional geothermal heat pumps are expensive and their performance is difficult to predict before installation. Researchers at the University of Minnesota are using this appropriation to develop, test, and demonstrate a novel geothermal heat pump technology that utilizes the heat exchange of groundwater flow to be more efficient, less space intensive, and less costly than current conventional geothermal systems. The technology has the potential to make geothermal heat pump systems have a faster payback period, resulting in more widespread use, and give geothermal a larger role in renewable energy production.

OVERALL PROJECT OUTCOME AND RESULTS

The objective of this project was to provide extensive numerical modeling and lab demonstration of a novel geothermal/groundsource heat pump (GHP) that was previously-devised and underwent initial modeling at the University of Minnesota.

GHP's can reduce energy requirements for heating/cooling, which account for approx. 48% of average US residential energy usage, by 75%. However, traditional GHPs are expensive, and their performance is difficult to predict before installation. Our novel, groundwater-enhanced GHP method/technology should substantially reduce GHP costs while improving performance and predictability by taking advantage of the thermal transport properties of groundwater in a closed-loop fashion so that no groundwater is used and no contaminants are introduced to the subsurface.

This project sought to determine whether the groundwater-enhanced GHP was technically feasible through a combination of detailed numerical simulation and simple lab tests. For the numerical modeling, we used the codes COMSOL and OpenGeoSystem to simulate operation of our GHP in a geologic environment, specifically examining heat transfer between the GHP and groundwater over a variety of temperatures and fluid flow rates. For lab testing, we constructed a simple, simulated GHP environment and a basic version of our novel heat exchanger, permitting the performance of this exchanger to be tested and compared against conventional GHP units. Our

numerical and lab results indicated that under a broad range of conditions, our novel GHP performs very effectively, with the practical result that fewer boreholes – as little as 1/5th to 1/10th – would be needed in real-world GHP installations using this approach as compared to conventional technologies. As boreholes are up to 50% of the cost of GHP installations, our method/technology should make GHP's more economically viable.

To follow this project and demonstrate commercial viability of the groundwater-enhanced GHP, we must next demonstrate the technology in a series of full field tests. To that end, we have several pending grant proposals submitted or in process, and we have engaged a local engineering firm to construct these field studies. Our ultimate objective is to increase the use of GHP's in MN and beyond, decreasing emissions and energy costs related to heating and cooling.

PROJECT RESULTS USE AND DISSEMINATION

To date, dissemination of project results has been limited in order to ensure that the design and performance of the novel groundwater-enhanced GHP remain confidential prior to filing of a patent application. As noted in the workplan, an intellectual property disclosure was submitted to the UMN Office for Technology Commercialization prior to initiation of this project.

Once a patent application has been submitted, we intend to submit our research for publication in a peer-reviewed journal.

Project Completed: 06/30/2017 [Extended in M.L. 2016, Chapter 186]

[FINAL REPORT](#)

Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources - RESEARCH

Subd. 08c \$1,000,000 TF

Roger Ruan

U of MN

1390 Eckles Ave

St Paul, MN 55108

Phone: (612) 625-1710

Email: ruanx001@umn.edu

Web: <http://biorefining.cfans.umn.edu/bioenergy-bioproducts-cluster/>

Appropriation Language

\$1,000,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to demonstrate innovative technologies to utilize and treat wastewater streams for conversion of treatment by-products to biofuels. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Each year Minnesota municipal wastewater treatment plants generate large amounts of oily scum, concentrated liquid called centrate, and sludge. These waste streams are disposed of either in landfills or by burning or subjected to additional treatment. However, new technologies have shown potential to capture resource values from these waste products while lowering the treatment costs for these waste streams. Researchers at the University of Minnesota are using this appropriation to demonstrate the feasibility and effectiveness of several technologies that implemented together in a wastewater treatment system could improve wastewater treatment while generating valuable biofuel byproducts. Expected benefits of the technologies include reduced landfill contributions, reduced fossil fuel use, cost savings and revenue generation for wastewater treatment plants, and reduced air and water pollution.

OVERALL PROJECT OUTCOME AND RESULTS

Minnesota municipal wastewater treatment plants (MWTP) generate large amounts of oily scum, concentrated liquid (also called “centrate”), and sludge each year. These waste streams are either used as landfill (scum) and direct burning (sludge), or subjected to additional treatment (centrate). The goal of the project was to demonstrate the feasibility and effectiveness of implementing innovative technologies in municipal wastewater treatment plants. Three main activities were carried out during the project: (1) Processes have been developed to convert wastewater scum to biodiesel meeting the relevant ASTM standards, (2) Processes have been developed for sustainable growth of microalgae on centrate and full utilization of nutrients in the centrate stream, and (3) new processes have been developed thermochemically convert sludge to high value energy and materials. During the research, the processes were evaluated for effectiveness and efficiency. Pilot scale systems for designed and fabricated for scum to biodiesel conversion, mass cultivation of microalgae on centrate supplemented by glycerol, and microwave assisted conversion of sludge to bioenergy and biomaterials. Four graduate students and four research scientists were involved and trained during the project. One patent for scum to biodiesel production was filed and one propitiatory technology for fast microwave assisted pyrolysis has been licensed to a company. More than 30 papers have been published on peer-reviewed journals. More than 10 presentations have been presented in state, national, and international meetings. Demonstration of the pilot systems has been given to Superior Process Technology, Resynergi Inc., Minnesga Inc., LZL Engineering, eVende, Metro Council Environmental Service. Media interviews have been given to Minnesota Daily, Channel 5, and Channel 11. The outcome of the project has significant impacts on Minnesota’s renewable energy production, environment conservation and protection, and economy and jobs. The new technologies can be implemented in mid to large size municipal wastewater treatment plants in Minnesota and elsewhere, producing significant amounts of renewable energy for internal use or to be distributed to the market, resulting in significant savings for waste management and disposal, generating considerable revenues.

PROJECT RESULTS USE AND DISSEMINATION

1. The research activities were used to train students and junior researchers. Research findings were used to enhance classroom teaching materials
2. Research findings were published in peer-reviewed papers (>30), presented in state, national, and international meetings (>10)
3. One patent was filed and one propitiatory technology has been approved and licensed to a US company
4. The technologies developed from the project have been demonstrated to various stakeholders
5. The project was reported by local newspapers and TV stations

Project Completed: 06/30/2017

[FINAL REPORT](#)

Transitioning Minnesota Farms to Local Energy

Subd. 08d \$500,000 TF

Mike Reese

U of MN

46352 State Hwy 329

Morris, MN 56267

Phone: (320) 589-1711

Email: reesem@morris.umn.edu

Web: <https://wcroc.cfans.umn.edu/research-programs/renewable-energy>

Appropriation Language

\$500,000 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 clean energy strategies for Minnesota farms in order to reduce fossil fuel energy use and increase local energy production. Any installation of infrastructure or improvements must be at the University of Minnesota West Central Research and Outreach Center. This

appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Production agriculture's dependence on fossil fuel energy carries significant economic and ecological risks. The energy consumed within livestock facilities alone is the equivalent consumption of several large cities, and agriculture currently contributes approximately 14% of the total greenhouse gas emissions in the state. As consumers increasingly demand low carbon footprint products, adoption of clean energy systems in crop and livestock production would position Minnesota's agricultural sector with a competitive advantage. While Minnesota farmers have historically adopted technology to more efficiently use resources and optimize production, implementation of clean energy technologies on farms has been slow to date and farmers continue to opt for conventional fossil-based energy. In response to this, researchers at the University of Minnesota West Central Research and Outreach Center are using this appropriation to develop, test, and evaluate options for clean energy systems for modern swine production facilities and conduct associated outreach to increase adoption of clean energy systems at these facilities.

OVERALL PROJECT OUTCOME AND RESULTS

Agriculture production requires large amounts of fossil energy. The use of fossil energy for agriculture impacts the environment, air, water, and economy. The goal of this project was to provide swine producers with research-based information enabling the transition to clean, locally-produced energy. The project was organized into four tasks.

The first task was to design clean energy systems for modern swine facilities.

- Energy consumption was audited at six commercial swine production facilities and the West Central Research and Outreach Center (WCROC).
- Facilities included breed-to-wean, nursery, and finishing buildings.
- Energy consumption data enabled rankings of energy loads for each phase of production.
- Results, for example, indicated that heat lamps for piglets used on average 49% of the electrical energy consumed in a farrowing facility. Producers would benefit by upgrading to energy efficient heating for piglets.
- An engineering firm analyzed several energy efficiency measures (EEM) appropriate for swine production to reduce energy consumption.
- Return on Investments (ROI) were calculated for each EEM.

Task two involved field testing of a clean energy system.

- A 27 kW solar PV system was installed and tested on the WCROC swine finishing facility.
- The system provided all energy consumed within the facility generating 30,000 kWhr per year.
- Solar PV system ROIs were modeled for commercial swine facilities. Installation costs are declining but incentives are still needed to achieve simple paybacks under 10 to 15 years.

Life Cycle Assessment (LCA) was employed in Task 3.

- LCA was used to analyze the amount of fossil energy consumed and carbon dioxide emitted during swine production. Energy improvements were also modeled.
- Results indicated the Global Warming Potential (GWP) emissions in the broader swine lifecycle were highest for feed production, which accounted for almost 60% percent of fossil energy and 50% of greenhouse gas emissions.
- Producers have management control on roughly 25% of the fossil energy consumed.
- On-farm renewable energy systems can significantly lower fossil energy use on farms.

Task 4 involved dissemination of results and education which is described below.

PROJECT RESULTS USE AND DISSEMINATION

The Midwest Farm Energy Conference was hosted at the WCROC in June 2017. Approximately 90 farmers and other guests participated in the event. Swine energy workshops were conducted in other regions of the State. Energy information was provided to producers, who in total, market over 3 million pigs per year and represent

over 90% of the State's annual production. In addition, energy curriculum was developed for agriculture and science educators teaching secondary and post-secondary technical students. The curriculum is being made available on-line. Additional materials including conference video and slide presentations can be accessed at <https://wcroc.cfans.umn.edu/research-programs/renewable-energy>.

Project Completed: 06/30/2017

FINAL REPORT

Task 1: Designing Clean Energy Systems

Task 2: Field Testing of Clean Energy Systems

Task 3: Life Cycle Assessment (LCA)

Task 4: Dissemination of results and education

Life Cycle Energy of Renewably Produced Nitrogen Fertilizers

Subd. 08e \$250,000 TF

Joel Tallaksen

U of MN

46352 State Hwy 329

Morris, MN 56267

Phone: (320) 589-1711

Email: tall0007@umn.edu

Web: <https://wcroc.cfans.umn.edu/green-nh3-lifecycle>

Appropriation Language

\$250,000 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 calculate fossil fuel energy savings and greenhouse gas reductions resulting from the use of local renewable energy technologies, including biomass gasification, anaerobic digestion, and hydroelectricity to produce fertilizer. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Minnesota supports over 14 million acres of cropland in grain production. Almost 600,000 tons of synthetic nitrogen fertilizers are needed annually to maintain productivity on this land, which requires the equivalent of 3,000,000 barrels of oil and costs farmers over \$400 million dollars per year. This amount of fossil fuel use results in a significant amount of greenhouse gas emissions, while the absence of fossil energy resources in the state means that these synthetic nitrogen fertilizers must be imported into Minnesota from other states and overseas. In response to this, researchers at the University of Minnesota West Central Research and Outreach Center are using this appropriation to conduct modeling and analysis of the viability of options for using different renewable energy technologies that could be implemented in Minnesota for generating nitrogen fertilizer. Findings have the potential to help reduce agricultural energy related production costs and make rural communities more energy independent.

OVERALL PROJECT OUTCOME AND RESULTS

The Minnesota landscape supports over 14 million acres of grain production, requiring almost 600,000 tons of nitrogen fertilizers and costing over \$400 million annually. Producing this fertilizer consumes the equivalent of 3,000,000 barrels of oil, which is a significant use of fossil fuels resulting in a considerable amount of greenhouse gas emissions. Minnesota has renewable technologies that are capable of the constant energy generation needed to produce ammonia, which would promote economic development, spur job creation in rural areas and improve the overall sustainability of agriculture. This project examined the viability of developing these baseload renewable energy sources for ammonia production.

Using life-cycle assessment and techno-economic modeling, the research examined ammonia production with three renewable energy options; gasification, anaerobic digestion and hydroelectric systems. The findings indicate that from both a technical and environmental standpoint, these renewable production systems can produce renewable ammonia fertilizer. However, the present economics make investing in renewable ammonia production unfeasible at this time. The current and continued low price of natural gas prices suggests that low cost fossil-based ammonia is a more economical option at this point. Past shortages and price spikes in ammonia fertilizers indicate that the economics and need for the systems might re-appear under different conditions. Yet, it is unlikely that these renewable ammonia systems would be viable in the short term without a significant consumer or other regulatory demand. Ammonia fertilizer is critical to Minnesota's agriculture and the information from this study is available should alternative ammonia production need to be implemented on short notice.

PROJECT RESULTS USE AND DISSEMINATION

The project used two main paths to disseminate scientific, technology, and economic information. The first was in-person via presentations to the wide variety of stakeholders interested in ammonia, agriculture, sustainability and rural development. Many of these interactions are during facility tours of the West Central Research and Outreach Center's agricultural renewable energy facilities and production systems. However, team members have given a variety of presentation and talks on renewable ammonia production and renewable energy to the chemical engineering and ammonia energy interests. This is in addition to general discussions on farming energy inputs and improving farming sustainability that we normally have at conferences, in classrooms, and at farming events. The international members of the team have broadened the in-person dissemination beyond the Midwest. The other main focus of dissemination is print and online media. Both can be used for reaching audiences that are not able to physically visit or meet with us at conferences. These formats also allow for informing audiences with a wide range of skills and interests. For the more academic audiences, we are developing a technical paper that will be published in an academic journal. The findings of the study are being written up as an internally published white-paper document for those interested in the practical finding from the work. Smaller summaries were developed as a handout for general audiences. All of these documents are or will be available on the project's website at <https://wcroc.cfans.umn.edu/green-nh3-lifecycle>. The site also has links to other ammonia, agriculture, and research topics being studied by the West Central Research and Outreach Center and University of Minnesota Researchers.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Renewable Hydrogen Energy Pilot Program](#)

[Modeling Anaerobic Digestion Based Ammonia Production](#)

[Gasification-Based Ammonia Ethanol Production Model](#)

Clean Water and Renewable Energy from Beet Processing Wastewater and Manure - RESEARCH

Subd. 08f \$400,000 TF

Shaobo Deng

U of MN - Southern Research and Outreach Center

35838 120th Street

Waseca, MN 56093

Phone: (507) 835-1495

Email: dengx007@umn.edu

Web: <http://sroc.cfans.umn.edu>

Appropriation Language

\$400,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Southern Research and Outreach Center in Waseca to research the cofermentation of sugar beet processing wastewater and swine manure for hydrogen and methane production and to install and evaluate a pilot-scale

system. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Minnesota ranks #2 in hog production and #1 in sugar beet production in the U.S., generating about 11 million tons of pig manure and over one million tons of sugar processing wastes annually. Presently there are not cost-effective methods available to deal with these waste streams other than land application, which usually results in nutrient runoff into ground and surface water resources. Better treatment of these waste streams is necessary, but treatment alone is not only expensive but usually fails to capture resource values contained within these waste streams that could be put to other uses. Additionally, these two waste streams together contain complimentary nutrients needed for biological processes such as fermentation and anaerobic digestion. Researchers at the University of Minnesota Southern Research and Outreach Center are using this appropriation to develop, test, and evaluate technologies that utilize these two different agricultural waste streams containing complementary nutrients to produce value-added byproducts in the forms of bioenergy and fertilizer while reducing the negative impact of both waste streams on water quality.

OVERALL PROJECT OUTCOME AND RESULTS

This project has developed a novel treatment system to co-treat swine manure with sugar beet processing wastewater and produce biohydrogen, biomethane, and a slow release fertilizer (struvite). Overall outcomes and results can be summarized in four parts:

1. A continuous biohydrogen and biomethane production process, taking swine manure with sugar beet processing wastewater as feedstock, has been investigated in a two-stage anaerobic sequencing batch reactor (ASBR) system. Three significant operational parameters (pH, hydraulic retention time (HRT), and total solids level (TS) of the swine manure) were identified and the optimal condition was determined to be pH 5.3, HRT 16.5h, and TS 0.78% for the biohydrogen stage with highest yield at 1.52 mol-H₂/mol glucose, while pH 6.9 and HRT 51h was determined for the highest biomethane yield of 0.21 g-CH₄/g-COD-feed;
2. A wet-scrubbing biogas purification system for cleaning both biohydrogen and biomethane gases was investigated with optimal gas flow rate at 0.84L/min and 1.32L/min, with 0.3M and 0.2M NaOH solution, 6 min and 9 min replacing interval, respectively, to achieve complete CO₂ removal;
3. A struvite precipitation reactor system with pH 9.0, Mg²⁺/PO₄³⁻ molar ratio at 1.5, air flow at 2 LPM for 30 mins determined for efficient struvite formation of 650 mg per liter upstream waste;
4. An integrated system including the above three units has achieved a daily production of 7.8L/d H₂, 28.3L/d CH₄, and 1.95g/d struvite, with removal efficiency of TS, COD, TN and TP at 49.6, 76.5%, 65.8% and 76.8%, respectively, with a negative net energy gain due to the small system size and relatively high running cost.

A pilot scale system with 1000-gallon daily loading was estimated to have a positive energy gain of 630 kWh/d and the payback period for its capital and running cost will be nearly 2 years not considering maintenance cost.

PROJECT RESULTS USE AND DISSEMINATION

Results produced from this project has been incorporated in teaching material for courses: BBE 4733/5733 – Renewable Energy Technologies at Department of Bioproducts and Biosystems Engineering, University of Minnesota, lectured by Xiao Wu, 2015-2016; BE 461 – Bioprocessing Engineering at Department of Biological Engineering, University of Idaho, lectured by Xiao Wu, 2017.

An oral presentation has been made at ASABE 110th Annual International Meeting, with paper#: #1701057, at Spokane, Washington. July 16-19, 2017. Presenters: Wu, S., S. Deng, J. Zhu. Title: Hydrogen and methane production from swine manure and sugar beet wastewater by a two-step ASBR system.

Dissemination of this project will continue with publishing refereed and non-refereed articles, talking to people in the concerned industries and the stakeholders, developing teaching materials in college and graduate levels,

demonstration of the complete system for co-treating swine manure and sugar processing waste molasses and education of stake holders and general public, etc.

Project Completed: 06/30/2017

FINAL REPORT

[Journal of Integrative Agriculture Paper Publication](#)

Next Generation Large-Scale Septic Tank Systems - RESEARCH

Subd. 08g \$258,000 TF

Bo Hu

U of MN

1390 Eckles Ave

St. Paul, MN 55108

Phone: (612) 625-4215

Email: bhu@umn.edu

Web: <http://bohu.cfans.umn.edu/>

Appropriation Language

\$258,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a dual utility large-scale septic tank system designed for nutrient recuperation, bioenergy generation, and environmental protection using a bio-electrochemical system. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Septic tank systems aim to treat sewage generated by homes and facilities that do not have access to centralized wastewater treatment plants. Currently 25% of the U.S. population relies on these systems as their primary means of wastewater treatment. However, the treatment capabilities of these systems are limited and so byproducts can contribute to degradation of water resources and other environmental problems and the systems emit instead of collect powerful greenhouse gases such as methane. Additionally, the systems are actually an untapped source for recovering nutrients for other uses. Researchers at the University of Minnesota are using this appropriation to develop, test, and evaluate technologies to improve large-scale septic systems to be more effective and capable of capturing valuable nutrients from the waste stream and generating bioenergy. The technologies could be integrated into existing septic tank systems and the information will be helpful to wastewater professionals in designing next generation septic systems.

OVERALL PROJECT OUTCOME AND RESULTS

Septic systems treat sewage generated from homes and mid-sized facilities that do not have access to centralized wastewater treatment plants. They are effective in retaining and degrading organic matters in the sewage, however, the tanks do not substantially decrease phosphorus nutrients in effluent. The nutrients may enter surrounding aquatic environment and have a negative impact in water bodies such as lakes and rivers. To overcome the limitation, we developed a novel septic system that is better at removing phosphorus and organic matter than conventional septic tanks by using a "microbial electrolytic cell" which uses electricity to promote biological reactions inside the tank. Different reactor designs, sizes and operational parameters were investigated, i.e., from laboratory scale to pilot scale. Laboratory scale experiments were carried out at the University of Minnesota - Department of Bioproducts and Biosystems Engineering and the pilot scale was tested at the Saint Paul Municipal Wastewater Treatment Plant of Metropolitan Council Environmental Services. A preliminary techno-economic assessment showed that around one third additional installation cost is needed to implement this technology, and this enables 50%-90% of the phosphorus removal from the sewage, compared to the conventional septic system. The collaboration with the Metropolitan Council Environmental Services led to the development of a new technology that can help communities effectively manage their wastewater treatment

systems and improve public health and the environment. The technology developed from this project, together with the information obtained from the techno-economic analysis, could be useful to thousands of rural communities and help decision-making process of trying the novel tank configuration. When communities effectively manage their wastewater treatment systems, public health and the environment are adequately protected while the community has the management structure in place over the long-term.

PROJECT RESULTS USE AND DISSEMINATION

The technology developed from this project, together with the information obtained from the techno-economic analysis, can be beneficial to Minnesota septic tank users, which account for about 20%-25% of its population. Besides the academic dissemination, a video of showcasing the pilot-scale testing system was posted in our website (<http://bohu.cfans.umn.edu/>) and youtube (<https://z.umn.edu/lccmr-video>) for general public access. Important and practical results from this project will also be disseminated in relevant workshops or in Onsite Sewage Treatment Program of UMN. During the study, project information, results, and major achievements have been disseminated through multiple ways. While we are preparing another two manuscripts for peer-reviewed publication, one paper was published. Four oral presentations were made in 2014 and 2016 AIChE conferences, and in 2015 and 2016 ASABE AIM conferences. Two posters were also presented in the Department of Bioproducts and Biosystems Engineering Showcase.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Subd. 09 Environmental Education

Minnesota Conservation Apprenticeship Academy

Subd. 09a \$392,000 TF

Jenny Gieseke

Board of Water and Soil Resources

520 Lafayette Rd N

St. Paul, MN 55155

Phone: (507) 381-3131

Email: jenny.gieseke@state.mn.us

Web: <http://www.bwsr.state.mn.us/>

Appropriation Language

\$392,000 the second year is from the trust fund to the Board of Water and Soil Resources in cooperation with Conservation Corps Minnesota to continue a program to train and mentor future conservation professionals by providing apprenticeship service opportunities with soil and water conservation districts. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Many of the most experienced conservation practitioners at local soil and water conservation districts throughout the state are nearing retirement, and with their departure will go much of their practical, on-the-ground knowledge, experience, and skills. Meanwhile, college students seeking to be the next generation of conservation practitioners have knowledge of emerging technologies and other innovations that can improve and contribute to current conservation efforts. Through this appropriation the Minnesota Board of Soil and Water Resources will work with the Minnesota Conservation Corps to continue a program that places students in apprenticeship positions with county soil and water conservation district offices throughout the state. This unique program provides an opportunity for interns to gain valuable in-the-field experience from current practitioners while sharing their knowledge with those practitioners about the newest ideas and solutions for meeting today's natural resource challenges.

OVERALL PROJECT OUTCOME AND RESULTS

Future conservation leaders need to be familiar with Minnesota's widely varying land-use practices, water and soil resources, plant and animal habitats, and landowner concerns if we hope to maintain the capacity of local organizations to deliver conservation on the ground. While college graduates with conservation-related degrees are knowledgeable in technology, theory, and research methods, they still need to develop their on-the-ground skills. Communicating with landowners and implementing quality projects are vital to the success of conservation efforts and best learned from seasoned professionals. The Conservation Apprenticeship Academy transfers knowledge from experienced Soil and Water Conservation District professionals to the next generation of conservation managers. Real-world experience gained with Soil and Water Conservation Districts (SWCDs) during their busy season is experience that textbooks cannot convey.

This project funded the placement of 30 apprentices in 2015, 31 apprentices in 2016, and 32 apprentices for the first part of 2017. During this time the apprentices stabilized erosion on 916,318 square feet of slopes, planted 61,201 plants, trees, shrubs and seedlings, maintained 22.6 million square feet of restored areas, collected 3,505 water samples and impacted 2,451 people through environmental education and outreach.

In addition to these environmental benefits, the program also has a positive impact on students and conservation districts. 100% of apprentices indicated they felt more prepared to work in the conservation industry as a result of the program, and would recommend it to others. 95% of the Districts were satisfied with the work their apprentices completed, and 99% said they would participate in the program again. Managers also indicated that the work conducted by the apprentices increased the amount of conservation practices delivered by their districts during the program period.

PROJECT RESULTS USE AND DISSEMINATION

Information from the project has been disseminated through reports to LCCMR, newsletters by BWSR and through the Conservation Corps newsletter, website and annual report. Information was also used to recruit apprentices. Communication and outreach activities include the aforementioned reports, press releases, and electronic newsletters. Additionally, BWSR and Conservation Corps staff conducted outreach to SWCDs to find optimal matches between districts and apprentices. Through the course of their work, the apprentices conducted significant outreach to land owners and residents in topics ranging from easement protection to water quality education.

Project Completed: 06/30/2017

[FINAL REPORT](#)

Urban Environmental Education Engaging Students in Local Resources

Subd. 09c \$1,093,000 TF

Meg Krueger

Wilderness Inquiry

808 14th Avenue SE

Minneapolis, MN 55414

Phone: (612) 676-9413

Email: meg@wildernessinquiry.org

Web: <http://www.wildernessinquiry.org>

Appropriation Language

\$1,093,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Wilderness Inquiry for a collaborative partnership, including the National Park Service, Minneapolis Public Schools, and St. Paul Public Schools, to establish a metrowide system providing place-based environmental education experiences using existing, but underutilized, outdoor environmental resources serving over 15,000 middle and

high school students. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

There has been a sharp decline in participation in outdoor recreation and education amongst youth, particularly in urban areas. Some argue that youth who have meaningful outdoor education experiences are more likely to become engaged in environmental stewardship and invested in outdoor resources as adults. Wilderness Inquiry - in partnership with state and federal agencies, non-profits, and local school districts - is using this appropriation to expand an environmental education and recreation program that provides youth with hands-on educational and recreational experiences centered around the Mississippi River. Funds enable the program to offer experiential, place-based educational experiences to nearly 16,000 additional disadvantaged middle and high school students in Minneapolis, St. Paul, and six greater Minnesota school districts. Experiences will include hiking, canoeing, fishing, aquatic sampling, camping, and conservation-related summer employment.

OVERALL PROJECT OUTCOME AND RESULTS

Wilderness Inquiry undertook this project of connecting youth to natural spaces in response to an observation that fewer and fewer young people access and enjoy nature than previous generations. With the growth of the urban population, resource management agencies were not in a position to connect young people to the Mississippi River and its surrounding parks and waterways. Through extensive partnerships with land management entities, federal agencies, local non-profit organizations, and school districts, Wilderness Inquiry exceeded the outcomes of this project by serving more than 25,000 Minnesota youth and families in the Twin Cities metro area and across the state.

- Wilderness Inquiry connected more than 21,000 youth to place-based, outdoor learning through single-day events on the Mississippi River, Minnesota State Parks, St. Paul and Minneapolis Regional Parks, and more.
- 2,794 youth engaged in deeper learning by participating in 2-3 day camping experiences as well as yearlong outdoor clubs. These experiences offered students the opportunity to gain comfort and confidence being outdoors. Fire building and shelter building activities were especially popular on these trips.
- 1,207 youth experienced 4-5 day camping trips or 40+ hours of experiential, place-based learning. These trips included paddling in the Boundary Waters Canoe Area or Voyageurs National Park, hiking in Superior National Forest, or multi-day events in the metro area, exploring the history and ecosystem of the Mississippi River.
- 148 students who participated in multi-day overnight exchange experiences introducing urban and rural youth to each other and the natural resources of each respective area. Despite the project ending in June 2017, Wilderness Inquiry will continue this program due to its success and growth over three years.
- Wilderness Inquiry trained and hired over 50 licensed teachers to lead programs and design content for this project. These professional development opportunities for teachers resulted in hundreds of youth learning MN state-standard curricula through place-based outdoor opportunities. The teachers expressed that they will use the skills they learned and the content they designed in their classes for many years. Empowering educators to connect their students to outdoor learning is one of the greatest accomplishments of this project, and its impact is yet to be truly known.

PROJECT RESULTS USE AND DISSEMINATION

Wilderness Inquiry successfully evaluated and disseminated the outcomes of this project through partnership with the University of Minnesota Center for Applied Research and Educational Improvement. Final report briefs from 2014-2016 evaluations can be found online for the general public at <https://www.wildernessinquiry.org/current-news/research-results/uwca-evaluations/>. Results have been shared with the Wilderness Inquiry staff to ensure continued improvements to training and program models. These findings have been shared at conferences and with our local partners including Minnesota Department of Natural Resources, Minnesota Department of Education, Minneapolis Park & Recreation Board, St. Paul Parks and Recreation, and others. Our work continues to be shared by our national partners including Children & Nature Network, City Parks Alliance, National Park Service,

and National Summer Learning Association. In July 2017, Wilderness Inquiry was selected from a group of finalists to receive a national education award for excellence and innovation in summer learning programs, read more about the honor at <https://www.wildernessinquiry.org/current-news/news-notes/wilderness-inquiry-wins-major-award-national-summer-learning-association/>.

Project Completed: 06/30/2017

[FINAL REPORT](#)

[Canoemobile Evaluation Brief 2016](#)

[Urban Wilderness Canoe Adventures Evaluation Brief 2015](#)

[Urban Wilderness Canoe Adventures Evaluation Brief 2014](#)

Diversifying Involvement in the Natural Resources Community

Subd. 09d \$500,000 TF

Subd. 09d1 - \$416,000 TF

Gina Bonsignore

MN DNR

1200 Warner Rd

St. Paul, MN 55106

Phone: (651) 259-5809

Email: regina.bonsignore@state.mn.us

Web: <http://www.dnr.state.mn.us/index.html>

Subd. 09d2 - \$84,000 TF

Raymond Newman

U of MN

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/>

Appropriation Language

\$416,000 the second year is from the trust fund to the commissioner of natural resources and \$84,000 is to the Board of Regents of the University of Minnesota to increase participation of under-represented communities in the natural resource professions and in outdoor recreation by means of targeted urban outreach and stronger linkages between Department of Natural Resources programs and academic offerings. This initiative must be coordinated with other environmental education appropriations in this subdivision. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Project Overview

Minnesota's natural resource professional workforce is much less diverse than its citizenry and many other professional fields. The benefits of a more diverse workforce are many, including the ability of organizations to increase innovation and creativity, attract higher qualified candidate pools, and ensure services that meet the diverse interests and needs of all citizens. The Department of Natural Resources and the University of Minnesota are using this appropriation to engage diverse urban youth, under-represented in the natural resources community, in natural resources education and developing outdoor recreational skills. Project efforts include connecting youth with close-to-home natural resource recreation and protection issues, a recruitment and retention program to introduce potential career opportunities, support and mentoring for those interested in pursuing natural resources college education and careers, and introductory experiences and internships in natural resources jobs.

DNR Project: OVERALL PROJECT OUTCOME AND RESULTS

The Minnesota Department of Natural Resources (DNR), Conservation Corps of Minnesota and Iowa (CCMI), University of Minnesota and US Forest Service (USFS) collaborated on a project targeting the lack of diversity in Minnesota's natural resource professional workforce. To increase involvement in our state's natural resource community, we engaged under-represented urban youth and their families in natural resource programming tailored to their interests and needs.

CCMI developed an employment and education program for high school youth from under-represented communities in the Twin Cities. Over three years, 220 youth received career and academic counseling as well as natural resource experiences. Of that group, 34 youth – “the Bridges Crew” participated in an intensive summer program working alongside DNR and other agency staff. Weekly enrichment days and in-the-field experiences engaged youth in the science of natural resources restoration and management. Their final three weeks were spent working in the Superior National Forest, funded by USFS. Youth evaluations revealed that this capstone experience cemented the bonding experience among crew and with the natural world and showed that 87% of youth had more awareness of and interest in natural resource and natural resource careers than at the start of the program.

DNR hired and mentored five student workers who researched issues and solutions to increasing diversity in natural resource activities and careers. Their work led to the production of career brochures and activities that are widely used by the agency and others to attract a more diverse workforce. These interns planned, organized crew projects and enrichment days. With DNR staff, they collaborated with partners to organize four annual events, marketed to and attended by under-represented communities, introducing over 1800 people per year to outdoor recreation. At these events, the interns shared information about careers and nearby opportunities to continue their outdoor adventures. A summary that outlines the program and lessons learned is available on CCMI's website.

DNR Project: PROJECT RESULTS USE AND DISSEMINATION

CCMI has created a Bridges page on their website that outlines the programs, goals and components of the Bridges Project (<http://www.conservationcorps.org/bridges>). Based on the work of project interns, the DNR produced a career guide and handouts that are aimed at attracting a more diverse workforce. The DNR has shared the career guide with all supervisors in the agency and will be posting them on their website for downloading. These materials are being used by our outreach staff and others, at career fairs and school visits throughout the state. A set of materials have been provided to college and career offices in Minneapolis and St. Paul high schools. The DNR continues to work with outside partners to continue our collaborations and accomplish new avenues to connect with new audiences. For instance, on Aug 12th we partnered with St. Paul Public Housing to have a nature bike ride, with residents enjoying the outdoors. CCMI, DNR and the US Forest Service will continue to collaborate on continuing components of the Bridges crew to the extent future funding will allow. Career engagement materials, activities and guidance documents will be shared with organizations we have work with throughout this project.

U of M Project: OVERALL PROJECT OUTCOME AND RESULTS

The lack of diversity in the natural resource workforce and its educational pipeline is problematic as the need accelerates for a qualified and diverse pool of professionals to replace the retiring generation. Many under-represented students are not aware of natural resources as an alternative to better-known science and engineering careers. To address this issue, the University, in coordination with the Conservation Corps of Minnesota (CCM) Department of Natural Resources (DNR), and US Forest Service (USFS) created a program for under-represented youth that bridged their natural resource work experience with university natural resource pathways and programs.

Overall, we engaged over 225 youth in campus activities in natural resources. During college and career days, youth toured labs and interacted with faculty and students. During summer enrichment days, 34 youth experienced a variety of research and management activities including assessment of invasive aquatics and water quality, bird banding, urban forestry, research at Cedar Creek Reserve and wetlands restoration. For many youth,

this was their first opportunity to handle a fish or a bird, or collect water quality and plant community data. Youth interacted with 8 different university faculty and numerous graduate students, learning about their career paths. Our staff and students valued this experience, as many are committed to enhancing the diversity of the next generation of natural resource professionals.

Post-program surveys showed that the youth gained awareness of and interest in natural resource education pathways and careers. However, our goal of enrolling as many of these youth as possible into the university's Post-Secondary Enrollment Option (PSEO) was less successful. Only two students were accepted into and participated in this highly competitive option. Focus of our work shifted to meet the needs of the youth recruited to work for CCM - counseling and mentoring students to pursue the whole range of college readiness options in high school. In conjunction with our project partners (DNR, CCM, USFS) we developed a collection of effective resource materials and engagement strategies that can be provided to high school youth in the coming years.

U of M Project: PROJECT RESULTS USE AND DISSEMINATION

Monthly meetings with project partners (DNR, CCM, Forest Service) allowed us to provide input to and share materials that were developed in addition to coordinating efforts.

We developed a composite summary flier outlining the three most relevant majors in natural resources at the University of Minnesota. We distributed those at youth events and also at various recruiting events used by us, CCM and the DNR to recruit youth to the CCM programs. We developed a Facebook group page to engage CCM youth and make them aware of opportunities; we shifted the group focus to alumni of the various youth programs with the aim to maintain a connection with opportunities after they left the corps.

We developed an extensive set of PSEO materials for distribution to youth and use by the CCM college and career counselor and crew leaders.

Supporting materials have been provided to our project partners (DNR, CCM, USFS) and we have a collection of programs and opportunities that can be provided to high school youth in the coming years. Internally, materials were shared with project participants and partners on a google drive. The materials are now deposited with the Conservation Corps and available from their website (<http://www.conservationcorps.org/bridges>).

Project Completed: 06/30/2017

[FINAL REPORT - Bonsignore: \(Subd. 09d1\)](#)

[MN DNR Career Guide: \(Subd. 09d1\)](#)

[MN DNR Career Sheets: \(Subd. 09d1\)](#)

[FINAL REPORT - Newman: \(Subd. 09d2\)](#)

Minnesota Pollinator Partnership

Subd. 09g \$100,000 TF

Drew Larsen

Pheasants Forever, Inc.

1783 Buerkle Circle

St. Paul, MN 55110

Phone: (308) 293-1194

Email: dlarsen@pheasantsforever.org

Web: <http://www.pheasantsforever.org>

Appropriation Language

\$100,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with Pheasants Forever to complete 40 community pollinator education and habitat projects. This appropriation must

be coordinated with appropriations provided by the outdoor heritage fund. 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, such as adding diversity of flowering plants to the landscape in order to provide nectar and habitat for pollinators. Pheasants Forever is using this appropriation to pilot an education and habitat restoration program in 40 communities around the state that will involve 800 youth and 200 adults in learning about pollinators and their habitat and engaging them in conducting community pollinator projects that establish pollinator foraging habitat on a total of at least 40 acres.

OVERALL PROJECT OUTCOME AND RESULTS

The Minnesota Pollinator Partnership was created because species like domesticated honey bees and monarch butterflies are experiencing alarming declines in their populations, and pollinating insects are an essential component in global food production. Our objectives of this program were to educate youth groups and the general public in MN about the value of pollinating insect species and the habitat on which they rely on to survive, provide hands-on opportunities for youth groups and the general public in MN to establish pollinator habitat projects, establish quality pollinator habitat projects that provides foraging habitat for native pollinators, and to create a model that would aide other Pheasants Forever (PF) chapters, land managers, biologist and the general public in MN in the establishment and maintenance of future pollinator habitat projects.

During the last three years, PF staff worked with our volunteer chapters and partners to engage youth groups and community groups across MN to establish pollinator projects. Small grants were offered to Pheasants Forever Chapters and our partners to establish pollinator projects. In order to take advantage of the grants, PF chapters and partners had to engage a youth group and/or community group in the establishment of a pollinator projects. In addition, PF chapters and partners had to provide educational activities and/or curriculum to those youth groups and community groups they were working with to establish the project.

Since the program's inception, we have helped establish 43 projects on 137 acres. There have been 4,297 individuals who have participated in a pollinator partnership event, and those volunteers have donated over 4,500 hours of time planning, planting, and maintaining project sites. In addition, the program has been so successful that it helped us build a model that has been replicated across the entire country; and we have now completed youth pollinator projects in 20 other states.

PROJECT RESULTS USE AND DISSEMINATION

Information from this project has been used and disseminated in the following ways:

- The program and projects have been promoted at Pheasants Forever meetings (i.e. District Meetings, State Meeting, Pheasant Fest, Professional Meetings, Program Website, Newsletters, Videos, Flyers, Facebook, Twitter, Press Releases, and News Paper Articles).
- The program has helped produce program standards that are now used across the country to implement Youth Pollinator Projects. We now have projects in 20 states outside MN that follow the same protocols developed for the MN Pollinator Partnership.
- In order to determine the impacts on those involved in the MN Pollinator Partnership, we distributed a survey and conducted post survey interviews with Pheasants and Quail Forever volunteers and staff members. Sixty-seven adult Pheasant Forever and Quail Forever Chapters volunteers responded to the survey.

Information created from this program will continue to be disseminated through Pheasants Forever channels. We

plan to continue and grow this program across MN and the Midwest with the materials we have created through the MN Pollinator Partnership.

Project Completed: 06/30/2017

[FINAL REPORT](#)