M.L. 2015 Projects

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

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

Subd. 03 Foundational Natural Resource Data and Information

Subd. 03g Minnesota Native Bee Atlas - $790,000 TF

Robert Blair
U of MN
1980 Folwell Ave, #200
St Paul, MN 55108

Phone: (651) 644-1591
Email: blairrB@umn.edu
Web: http://www.minnesotamasternaturalist.org

Appropriation Language
$790,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to supplement and enhance existing bee survey efforts by engaging citizens in helping to document the distribution and phenology of wild Minnesota bees and integrating data from all related bee survey efforts into a single publicly accessible, online tool and repository. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
The Minnesota Bee Atlas relied on volunteers to collect data on native bee distribution and diversity as well as previously unstudied nesting phenology. This data supplements existing information from the Minnesota DNR and UMN Insect Collection and can inform land management and policy decisions.

OVERALL PROJECT OUTCOME AND RESULTS
Although the plight of bees and other pollinators has been highlighted recently, the question of how bees are doing is complicated. There is still much to be known about which bees live where in Minnesota and their population status. From 2015 through 2019, volunteers documented over 25,000 bees in Minnesota as a part of the Minnesota Bee Atlas. They did this by submitting photos of bees to iNaturalist, adopting roadside survey routes to capture, identify and release bumble bees, and monitoring nesting blocks for stem-nesting bees.

Through this work, five species were documented that had previously not been recorded in Minnesota. While it's difficult to know if they are new arrivals or just newly documented, Minnesota is at the northern end of the range for 3 of those species and could be evidence of shifting ranges.

Non-lethal bumble bee sampling led to documentation of additional populations of the federally endangered rusty patched bumble bee (Bombus affinis). This data informs the US Fish and Wildlife Service species recovery plan.

The Bee Atlas documented nest structures and nest activity for stem-nesting bees that had not

previously been recorded. This information may inform management decisions that would impact the amount of forage or nesting habitat available for bees as changes could be made at times when bees are less active.

Finally, the Bee Atlas engaged members of the public beyond volunteer participants when volunteers became active in their own communities. Volunteers shared their knowledge of bees and pollinator conservation with youth scout groups, 4-H youth, Master Gardeners, Master Naturalists, and countless friends and neighbors.

PROJECT RESULTS USE AND DISSEMINATION
All records from the Bee Atlas can be found in publicly accessible databases, namely iNaturalist.org and the Minnesota Biodiversity Atlas. Additionally, species-specific information such as seasonality, floral associations, and identification for bumble bees and stem-nesting bees can be accessed through the University of Minnesota Extension. All volunteer training documents are also found on this page.

Publications relating to this work have been published in the Journal of Melittology and The Great Lakes Entomologist.

Project Completed: 06/30/2021
FINAL REPORT
Record of Anthophora (Clisodon) terminalis in a wooden trap-nesting block and comparison to available nesting information (Hymenoptera: Apidae) by Colleen Satyshur
Minnesota State Records for Osmia georgica, Megachile inimica, and Megachile frugalis (Hymenoptera, Megachilidae), Including a New Nest Description for Megachile frugalis Compared with Other Species in the Subgenus Sayapis by Colleen Satyshur

Subd. 06 Aquatic and Terrestrial Invasive Species

Sub-Project 01: Garlic Mustard Biocontrol: Ecological Host Range of Biocontrol Agents - $570,173 TF

Roger Becker
U of M - Department of Agronomy and GeneticsC
411 Borlaug Hall, 1991 Upper Buford Circle
St Paul, Minnesota 55108

Phone: (612) 625-5753
Email: becke003@umn.edu
Web: http://appliedweeds.cfans.umn.edu/personnel

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
We were integral in the release of Ceutorhynchus scrobicollis in Canada, the first biological control agent for garlic mustard in North America. We moved closer to federal regulatory approval to release C. scrobicollis and C. constrictus in the United States. When achieved, these will offer the first viable control of garlic mustard in Minnesota woodlands.
OVERALL PROJECT OUTCOME AND RESULTS

Garlic mustard poses significant threats to our forest ecosystem. Research supported by this grant develops effective biological control of garlic mustard in Minnesota, the United States, and Canada, offering the first viable control option for this troublesome invasive plant. We gained a recommendation that Ceutorhynchus scrobicollis be considered for a release in the U.S. from the APHIS PPQ Technical Advisory Group. In follow-up consultation between USDA-APHIS-PPQ and USFWS, questions were generated that were intended to expedite writing the Biological Assessment for C. scrobicollis. Funding from this grant enabled us to address those questions with specific research on three federally listed species. COVID-19 altered our timeline, yet we will be submitting the third edition of the response in August 2021. This funding supported Entomology PhD candidate Mary Marek-Spartz analyze predictive tools used to determine the expected range of biological control insects introduced to a new region, define specific biological thresholds of C. scrobicollis, and develop a novel biennial stage-structured plant-herbivore population model. She improved the accuracy of this model through data generated in our monitoring efforts funded from this grant. Also supported on this grant, Project Scientist Dr. Katovich further defined the vernalization requirements for a garlic mustard which will greatly improve the accuracy of the projected range of garlic mustard in the US, a key factor in determining the risk of introducing specific biological control insects to North America. Additionally, she completed host specificity testing for C. scrobicollis and made significant progress towards completing the registration package for C. constrictus. We have a draft of the petition for the release of C. constrictus for biological control of garlic mustard. Due to technical difficulties in rearing threatened and endangered species out of their normal habitats, we will complete the few species needed at CABI, Delémont CH.

PROJECT RESULTS USE AND DISSEMINATION

Knowledge gains have been distributed widely through professional and land manager meetings. Additionally, we presented our findings to our colleagues at the triennial International Symposium on the Biological Control of Weeds, hosted in 2018 by our cooperators from CABI, CH. Generations.py is a software program publicly available with a novel biennial component enabling modelers to improve predictions of the dynamics and biology of biennial organisms. We played a key role in the first release of a biological control insect for garlic mustard in North America. Additionally, four to six papers will be published in professional journals. A petition for the release of C. constrictus will be submitted to USDA APHIS PPQ TAG this fall or early next spring.

Subproject 01 completed: 06/30/2021

FINAL ABSTRACT

Sub-Project 02: Mountain Pine Beetle, Phase II: Protecting Minnesota - $445,347 TF

Dr. Brian Aukema
U of M - Minnesota - MITPPC
432A Hodson Hall, 1980 Folwell Ave
St Paul, MN 55108

Phone: (612) 624-1847
Email: baukema@umn.edu
Web: https://www.entomology.umn.edu/faculty-staff/brian-aukema

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Repeated surveys did not find mountain pine beetle in Minnesota. Scant few individuals were captured dispersing far from active infestations in western states. We found that local bark beetles and predators do not optimally recognize the insect's chemical signals, however, suggesting that such components of invasion resistance might be low.

OVERALL PROJECT OUTCOME AND RESULTS

Surveys over the course of this project did not detect any mountain pine beetle in Minnesota. Although absence data cannot rule out inappropriate lure choices, testing of a new lure within the Black Hills of South Dakota where mountain pine beetle is endemic found that the conventional lure worked well. No improvements were noted when testing a new formulation. Long distance dispersal transects revealed that mountain pine beetles can be captured up to 30 miles away from active tree-killing outbreaks, but these singletons represented a fraction of a fraction of the population. Dispersal pressure was much lower in the last year of the project when beetles returned to endemic levels, which is the norm in western forests for decades at a time. Thus, we expect that the risk of mountain pine beetle reaching Minnesota by blowing from infestations in the Black Hills of South Dakota, which is approximately 500 miles away from the nearest mature pine forests in Minnesota, is extremely low. If mountain pine beetle was to arrive in Minnesota, it would have to establish into an environment with new flora (species of pines) and fauna (other species of bark beetles as well as their predators) to which it had never been exposed. The only species of pine common to the Black Hills and Minnesota is Scots pine; exposures to the fungus that mountain pine beetle carries revealed strong localized responses of Scots pine to the inoculation sites with defensive chemicals known as monoterpenes. Surveys of Minnesota's community of bark beetles, competitors, and predators responding to lures of mountain pine beetle in comparison to similar in the Black Hills revealed nuanced, regional variations in responses, but overall strong fidelity to cures of predators associated with local prey. Thus, we expect that predators or competitors in Minnesota would not optimally recognize the aggregation pheromone of mountain pine beetle. In one case with direct comparative tests in the Black Hills, we noted that one of the most common bark beetles that would potentially compete with mountain pine beetle in Minnesota, Ips grandicollis, avoids the lure of mountain pine beetle. We did note a few mountain pine beetles in traps baited with the aggregation pheromone of Ips grandicollis when the traps were placed far from active infestations of mountain pine beetle. This finding suggests that mountain pine beetle could respond to such pheromones as a "last-ditch" effort to find habitat during endemic periods where there are insufficient numbers to mass-attack, colonize, and kill large trees. If true, mountain pine beetle could find an endemic niche in Minnesota's pine forests. Because we still lack knowledge about how mountain pine beetles persist in endemic states, and whether colonization densities might actually be lower in other species of Minnesota's pines if they have lower defensive responses, continued vigilance against mountain pine beetle as a threat to Minnesota's pine forests is warranted.

PROJECT RESULTS USE AND DISSEMINATION

We have published one scientific paper from this work, with four more moving toward publication with peer-reviewed journal targets. We gave numerous regional, national, and even presentations as venues such as the Entomological Society of America, the IUFRO Conference on Biological Invasions in Forests, the North American Forest Insect Work Conference, North Central Forest Pest Workshop, Western Forest Insect Work Conference, Upper Midwest Invasive Species Conference, the Sustainable Forest Education Cooperative, State Forest Health Cooperators, Northern Advanced Silviculture Program, Minnesota Forest Industries, and MN Department of Natural Resources Forestry Team.

Subproject 02 completed: 12/31/2021

FINAL ABSTRACT
Colonization and reproduction of potential competitors with mountain pine beetle

---

Sub-Project 03: Biological control of the soybean aphid by Aphelinus certus - $479,859 TF

George Heimpel
U of M - Department of Entomology
1980 Folwell Ave
St Paul, MN 55108

Phone: (612) 624-3480
Email: heimp001@umn.edu
Web: https://www.entomology.umn.edu/faculty-staff/george-heimpel

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Results of this study indicate that the parasitoid Aphelinus certus provides sufficient mortality of soybean aphids to substantially decrease the need to apply insecticides against this pest.

OVERALL PROJECT OUTCOME AND RESULTS

Prior to the year 2000, the approximately seven million acres of soybeans in Minnesota suffered very little insect damage and were seldom subjected to insecticide applications. This changed with the arrival of the soybean aphid from Asia during that year. This aphid rapidly became the most important insect pest of soybeans due to its ability to substantially lower soybean yield when present at high densities on plants. This led to a 'new normal' that included widespread insecticide use in soybeans in Minnesota, with areas in excess of one million acres sprayed in bad aphid years. While predatory insects were capable of suppressing populations in some years, this level of control was not consistent. We noted the arrival of a new natural enemy of soybean aphid in Minnesota in 2011, however – the parasitoid Aphelinus certus – that appeared to have the potential to be a game changer. This insect lays its eggs into soybean aphids, and the developing larvae kill the aphids from within. Our main objective was to determine the extent to which this parasitoid could control populations of soybean aphids below the level that necessitates insecticide use. We also hoped to elucidate agronomic strategies that could lead to increased control by this parasitoid. Based upon a combination of laboratory, field and theoretical studies, we were able to show that A. certus is indeed capable for suppressing soybean aphid densities below the threshold levels that farmers use to initiate insecticide use. Our theoretical simulations suggested that such control occurs in approximately 10% of fields during a given year. These studies also pointed to overwintering success of the parasitoids as a critical factor determining the strength of aphid suppression. It therefore stands to reason that any agronomic factors that increase overwintering success improve the parasitoid's capability of suppressing soybean aphid.

PROJECT RESULTS USE AND DISSEMINATION

This research led to new analytical tools to analyze the ability of the parasitoid Aphelinus certus to control populations of the soybean aphid. It also provided novel information on the primary overwintering site of the parasitoid (within soybean fields) and aspects of its overwintering and diapausing strategy. This information can be used to predict when A. certus adults will emerge in a given field season. Lastly, the research quantified the extent of control provided by this parasitoid and generated novel hypotheses for how control can be improved.

We generated an analytical tool using a stage-based matrix modeling approach and published it in an open access Journal. This model can be modified based on environmental and life-history characteristics for this or similar host-parasitoid systems and the underlying R code is available upon request from the authors.

Subproject 03 completed: 09/30/2021

FINAL ABSTRACT

A matrix model describing host–parasitoid population dynamics: The case of Aphelinus certus and soybean aphid

---

Sub-Project 04: Decreasing Environmental Impacts of Soybean Aphid Management - $570,000 TF

Dr. Robert Koch
U of M
1980 Folwell Ave
St Paul, MN 55108

Phone: (612) 624-6771
Email: koch0125@umn.edu
Web: https://www.entomology.umn.edu/faculty-staff/robert-koch

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Management of soybean aphid relies on applications of broad-spectrum insecticides. This work aimed to decrease insecticide use and ameliorate associated environmental impacts through development of aphid-resistant soybean and advancement of remote scouting.

OVERALL PROJECT OUTCOME AND RESULTS

The invasion of US soybean by the soybean aphid resulted in dramatic increases in insecticide use, which has increased production costs for farmers and environmental and human-health risks. This proposal takes a two-pronged approach (preventative and therapeutic) to improve management of the soybean aphid through decreased insecticide input, which will result in increased environmental and economic sustainability of soybean production. Integration of preventative and therapeutic pest management tactics is fundamental to integrated pest management (IPM). For preventative management, we advanced the development and availability of aphid-resistant soybean. This included advancement of numerous resistant soybean lines already in the soybean breeding pipeline, including commercial release of one line. Furthermore, numerous crosses were made to incorporate different combinations of aphid-resistance genes into soybean lines, and to test and advance them through the pipeline. Novel research was also performed to examine the variability in susceptibility of aphid populations to these aphid resistant lines. For therapeutic management, we advanced the ability to use remote sensing for soybean aphid through a series of field experiments and technological advancements. Through caged experiments and open-field experiments, we documented that aphid-induced stress to soybean can be detected from drone-based sensors. In addition, through additional caged experiments we found that typical levels of defoliation (<5%) from another insect, the Japanese beetle, is unlikely to affect the ability to scout for soybean aphid; however, higher levels of defoliation (>33%) could impact scouting for

soybean aphid. In addition, we built hardware to host new algorithms for autopilots used to guide small drones for accurate and safe pest management missions. We have tested the algorithm in simulation and by post-processing data collected from flight tests. These advancements will help farmers prevent soybean aphid outbreaks through the use of aphid-resistant soybean and to more effectively respond to outbreaks through efficient drone-based scouting.

PROJECT RESULTS USE AND DISSEMINATION

An aphid-resistant variety stemming from the work has become commercially available. Results of this project have been actively disseminated to stakeholders and the scientific community. Project results were shared in extension presentations to farmers and agricultural professionals throughout the life of this project and a video was created for stakeholders. A publication for stakeholders listed available resistant soybean varieties. Updates on this work were also shared at several scientific conferences. This work has led to scientific publications on remote sensing applications and technology (2019, 2020, 2021), and aphid-resistant soybean, and led to detection of a new soybean pest.

Subproject 04 completed: 12/31/2021

FINAL ABSTRACT

Observability and Performance Analysis of a Model-Free Synthetic Air Data Estimator
Two-Stage Batch Algorithm for Nonlinear Static Parameter Estimation
Variation in Soybean Aphid (Hemiptera: Aphididae) Biotypes Within Fields
First Reports of Macrosaccus morrisella (Lepidoptera: Gracillariidae) Feeding on Soybean, Glycine max (Fabales: Fabaceae)
Detection of Stress Induced by Soybean Aphid (Hemiptera: Aphididae) Using Multispectral Imagery from Unmanned Aerial Vehicles
Air data fault detection and isolation for small UAS using integritymonitoring framework

---

Sub-Project 05: Optimizing Tree Injections against Emerald Ash Borer - $320,000 TF

Brian Aukema
U of M - Department of Entomology
1980 Folwell Ave
St Paul, MN 55108

Phone: (612) 624-1847
Email: BrianAukema@umn.edu
Web: https://www.forest-insects.umn.edu

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

Emerald ash borer continues to spread and devastate Minnesota's urban forests, but deploying the right types of insecticides to ash trees in the right ways can offer tree conservation and protection with minimal risk to non-target organisms such as bees that visit flowers and worms that decompose leaves.

OVERALL PROJECT OUTCOME AND RESULTS

Emerald ash borer is an invasive insect that kills mature ash trees and has been spreading within Minnesota since its detection in 2009. Ash is a major component of many of Minnesota's urban forests. Injections of insecticides into ash trees can preserve trees indefinitely, but raises concerns for non-target

organisms in the environment such as bees and earthworms. For this study, we injected subsets of 1200 trees located in eight different cities in Minnesota with two different insecticides. We specifically tested products that were not neonicotinoids that have presented past risks to pollinators. Insecticides were injected into the trunks in summer of 2017, with periodic reapplications until 2020 while we measured crown health of each tree each summer until 2021. The original site selections were in cities with low pressure from emerald ash borer. We found over the four years of the study that injecting only half of the trees in a given site gave good protection to all trees. We were unable to determine, however, whether this associational protection (i.e., preservation of canopy in an untreated tree when proximate to a treated tree), winter mortality to EAB, or some combination of both was responsible for the site-wide excellent conditions that persisted five years after EAB was present in these communities. Measurements of tree phenology such as leaf out and leaf drop showed that insecticides did not alter the timing of such events. One of the insecticides, emamectin benzoate, showed excellent protection of ash seeds against seed weevils by the third year of the study, without affecting seed viability. We also canvassed the insect communities that visited the trees and harvested leaves for feeding trials with nontarget organisms, and measured chemical concentrations in the leaves. We found that insects communities were similar between treated versus untreated trees across seasons, that bees preferred visiting synchronously flowering plants such as flowering crab apples and rhododendrons versus ash trees, that trunk-injected chemicals were not reliably detected in all plant parts after injection, and that invertebrates such as worms showed no reduction in reproduction or feeding on treated leaves. As such, we concluded that detrimental effects of the insecticides tested on non-target organisms are not likely to be ubiquitous or widespread. In summary, when homeowners or communities are selecting a product to preserve urban ash trees, we recommend emamectin benzoate as a suitable and effective alternative to neonicotinoid-based products.

PROJECT RESULTS USE AND DISSEMINATION

This work has been submitted for publication at two peer-reviewed journals, with two more submissions planned. The work has been presented at regional, national, and international venues including workshops and conferences such as the Shade Tree Short Course, the Entomological Societies of Canada and America, the IUFRO Conference on Biological Invasions of Forests, the North American Forest Insect Work Conference, the Upper Midwest Invasive Species Conference, the USDA Interagency Annual Forum, and the North Central Forest Pest Workshop. A number of presentations were also given to local community forestry and resource manager groups throughout the project, and we enjoyed a high number of interactions with members of the public while working in their communities.

Subproject 05 completed: 12/31/2021

FINAL ABSTRACT

Effects of systemic insecticides against emerald ash borer on ash seed resources

---

Sub-Project 06: Distribution and Traits of the Fungal Pathogen Fusarium Virguliforme that Influence Current and Future Risk to Soybean and Other Legumes in Minnesota - $383,581 TF

Dean Malvick and Kathryn Bushley
U of M - Department of Plant Pathology
1991 Upper Buford Circle
St Paul, MN 55108

Phone: 612-625-5282

Email: dmalvick@umn.edu
Web: https://plpa.cfans.umn.edu/people/faculty/dean-malvick

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project has discovered factors that influence the ability of the fungus Fusarium virguliforme to become established as a destructive pathogen on crops in new areas of Minnesota. The results are foundational to understanding this pathogen and contribute to managing the diseases it causes on soybean and other crops.

OVERALL PROJECT OUTCOME AND RESULTS
The fungal pathogen Fusarium virguliforme, which causes sudden death syndrome (SDS) on soybean and root rot of other legumes, is an expanding problem for crop producers in Minnesota. Our research team has made discoveries regarding the pathogen's ability to spread and cause disease. First, a survey has confirmed the spread of the pathogen for the first time into seven counties in central and western MN. Second, studies of nutrient use suggest that F. virguliforme grows on a larger number of carbon and nitrogen sources than many other fungi in crop fields, likely giving it a competitive advantage. Analysis of competition between F. virguliforme and other fungi from crop fields revealed that while several fungi can inhibit its growth, multiple others are overcome by the pathogen, indicating it is a good competitor in soil and roots. Third, we determined it can survive to -40°C and thus its spread is not likely limited by cold temperatures. Fourth, in field and greenhouse experiments investigating host range, multiple crop species (black bean, pinto bean, kidney bean, and pea) showed symptoms of disease, and multiple other plant species were infected asymptomatically. Fifth, we completed a study and a publication on genetic and pathogenic variation among F. virguliforme populations in Minnesota and the Midwest. While genetic groups did not correspond to aggressiveness, three genetic clusters were identified, with two clusters likely contributing most to spread of this fungus. Sixth, we completed initial analysis of genomes from 35 isolates to investigate genes involved in pathogenicity and abilities to invade new environments. The projected trained one M.S. level and one postdoctoral level scientist, expanding expertise for addressing invasive plant pathogens. This project significantly advances fundamental and applied knowledge of F. virguliforme that can be harnessed for disease management and risk analysis by scientists, agricultural professionals, and crop producers.

PROJECT RESULTS USE AND DISSEMINATION
This project has discovered multiple factors that influence the ability of F. virguliforme to spread and become established as a destructive pathogen on crops in new areas. Results have been presented via University of Minnesota Extension programs to key agricultural professionals and crop producers across Minnesota that contribute to managing this pathogen and the crop diseases it causes. Results have also been presented at scientific conferences and are being published in scientific journals.

Subproject 06 completed: 06/30/2021
FINAL ABSTRACT

Sub-Project 07: Tools to Distinguish Native from Exotic Reed Canary Grass - $263,273 TF

Neil O. Anderson
U of M - Department of Horticultural Science
286 Alderman Hall

1970 Folwell Avenue
St Paul, MN 55108

Phone: (612) 624-6701
Email: ander044@umn.edu

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

This project used genetic techniques to find that most reed canarygrass in Minnesota is native to the state and not from Europe. Plant DNA was extracted from samples of reed canarygrass across the state. Due to this outcome, Tribal and State managers may choose to manage or preserve this species differently.

OVERALL PROJECT OUTCOME AND RESULTS

The goal of this project was to use molecular markers to determine native vs. exotic reed canary grass status in various locations across Minnesota growing along rivers (Des Moines, Minnesota, Mississippi, Red, Roseau, St. Croix), in fields, as commercially-grown cultivars (forage, ornamental), and preserved historic specimens in herbaria (<1940, presumed native) and a corollary set of samples from rivers in the Czech Republic as exotic comparisons (Activity 1); along Minnesota transportation corridors (highways) existing during the 1920s-1930s (Dust Bowl era) and Minnesota lakes (Bush, Cedar, Como, Phalen, Mille Lacs, Minnetonka, Square, White Bear) and Central Park (Activity 2). Due to Covid-19 travel restrictions, we were unable to get permission to collect along additional lakes. The number of plants analyzed totaled 3,430 (Activities 1,2). Plant DNA was extracted from each sample to determine genomic markers of short DNA sequences (2,889 highly differentiated single nucleotide polymorphisms, SNPs, out of 16,902 total markers) to distinguish native vs. exotic status. Genetic analysis of reed canarygrass showed that river populations are native Minnesota or North American types. Herbarium samples as well those from a native, unplowed field (Roseau, MN) were genetically similar to wild collections from five Minnesota rivers; forage cultivars in commercial fields (Roseau, MN) and along the Roseau River formed a separate group. The exotic central European populations were distinctly different from all native MN groups. Most variation is within (98.8%), rather than among (1.2%), populations, suggesting little divergence and a high level of shared genetic markers. Across the state, Minnesota rivers had 2-32 genetic variants present, some of which were shared among rivers. Thus, the majority of Minnesota reed canarygrass, while invasive, is native in origin and not exotic (European). Thus, based on this study, all of MN reed canarygrass is native; Tribal and State managers may choose to preserve this species.

PROJECT RESULTS USE AND DISSEMINATION

Dissemination of native vs. exotic status of all Phalaris results from Activity 1 has been reported on the Department of Horticultural Science website (http://horticulture.umn.edu), that of the PIs (http://horticulture.umn.edu/directory/faculty/neil-oanderson), as well as in all PIs/co-PIs Experts at umn.edu links (https://experts.umn.edu/). As many as 11 abstracts were published in national and international meetings, along with corollary public posters sessions or seminar talks to varied audiences of academics, land managers, students, and/or the public-at-large. We have kept State and Tribal Land Managers informed on the native status of MN reed canarygrass and have initiated discussions on approaches to managing this native species yet invasive. The investment by the state on control measures for this invasive grass warrant careful consideration of best management approaches to maintaining the native genetic diversity yet not encouraging the invasive spread of this grass into managed areas. Results were also communicated to the scientific community in peer-reviewed journal articles.

Subproject 07 completed: 06/30/2020
FINAL ABSTRACT

Sub-Project #8. Accurate detection and integrated treatment of oak wilt *(Bretziella fagacearum)* in Minnesota - $356,382 TF

Jeannine Cavender-Bares
U of M - Department of Ecology, Evolution and Behavior, College of Biological Sciences
1475 Gortner Avenue
St Paul, MN 55108

Phone: (612) 624-6337
Email: cavender@umn.edu
Web: http://cbs.umn.edu/cavender-bares-lab/home

SOUND BITE OF PROJECT OUTCOMES AND RESULTS

This project developed methods and approaches for better detection of oak wilt using spectroscopic technology and documented best practices to prevent spread of the disease.

OVERALL PROJECT OUTCOME AND RESULTS

Our team has made substantial progress on the development of methods and approaches for accurate detection of oak wilt in Minnesota forest using spectroscopic technology. We have also documented best practices for management efforts to prevent spread of the disease. Specifically, we have completed physiological experiments demonstrating the disease can be differentiated from other stress factors under controlled conditions (Activity 1). A manuscript on the greenhouse seedling experiment using leaf and whole plant spectroscopic data to differentiate oak wilt from bur oak blight and drought has been published in Tree Physiology. We have advanced analyses and ground-truthing of AVIRIS NG airborne imagery including model development and spectral index development for stress physiology in response to the oak wilt disease (Activity 2). In an outdoor field experiment using naturally growing oak saplings at the Cedar Creek Ecosystem Science Reserve, oak saplings were inoculated with oak wilt and compared to healthy saplings using leaf and canopy spectroscopy. Results indicate that physiological disease symptoms can be readily detected using spectral sensors at both leaf and canopy scales using statistical models and simple indices from spectral features linked to physiological stress. Lastly, treatments were completed at 20 oak wilt sites with a new “double plow line” to prevent spread of the disease through root grafts. Initial assessments indicate the approach is highly effective, but a final determination will be made 5 years after treatment, beyond the life of this project (funding secured from USDA Forest Service). Two postdoctoral scientists, a technical scientist, a first-year graduate student and two undergraduate research assistants received training and mentoring during the project.

PROJECT RESULTS USE AND DISSEMINATION

Our team has disseminated new knowledge from this project to local, regional, national and international audiences. A significant peer-reviewed publication has already come this project (Beth Fallon, Anna Yang, Cathleen Lapadat, Isabella Armour, Jennifer Juzwik, Rebecca A Montgomery, Jeannine Cavender-Bares. 2020. Spectral differentiation of oak wilt from foliar fungal disease and drought is correlated with physiological changes. Tree Physiology 40(3): 377–390, https://doi.org/10.1093/treephys/tpaa005). Others are in development. The team delivered 11 talks,

three posters, and one field tour to professional audiences. In addition, the project was featured in The Minnesota Daily and Market Science (scientific engagement at farmers' markets).

Subproject 08 completed: 06/30/2020
FINAL ABSTRACT

Sub-Project 10: Management Strategies for the Invasive Spotted Wing Drosophila - $478,876 TF

Mary Rogers
U of M - Department of Horticultural Science
1970 Folwell Ave
St Paul, MN 55108

Phone: (612) 624-8871
Email: roge0168@umn.edu
Web: http://fruit.cfans.umn.edu

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Our project developed new cost-effective methods to help growers manage damage and reduce yield loss caused by the invasive Spotted-wing drosophila in small fruit while reducing pesticide use. Additionally, we have gained basic knowledge on the behavior and flight capabilities of this pest that will contribute to future management strategies.

OVERALL PROJECT OUTCOME AND RESULTS
Spotted wing drosophila (Drosophila suzukii, SWD) is an invasive fly that lays eggs in intact, ripening fruit such as blueberries, strawberries, and raspberries. This pest has caused considerable economic losses for small fruit growers. First detected in MN in 2012, SWD threatens 750 acres of raspberries, strawberries, grapes, and blueberries, in addition to its 5,000 high tunnel operations statewide. At the start of our project, current control tactics were limited to repeat applications of broad-spectrum insecticides that failed to adequately protect fruit from infestation, in addition to posing risks to the environment. Additionally, we faced gaps in understanding the basic biology ad behavior or SWD, such as migration and overwintering in Minnesota, which hindered our ability to recommend appropriate management strategies. To address this, we proposed three goals: 1) develop SWD forecasting tool using local migration and overwintering data; 2) investigate efficacy of alternative management techniques; and 3) research economic impact and develop decision making tools. As a result of our work, we have indirect evidence showing that SWD may be overwintering and little evidence that the SWD has the flight capabilities for long-distance movement. We learned that physical exclusion can effectively reduce SWD damage and is cost-effective for small farms and reduces the need for insecticide sprays. Our work on biopesticides and novel repellants shows promising results in the lab but is less consistent in the field, warranting new methods to increase field efficacy. Economically, we found that SWD is responsible for at least $2 million in losses annually to raspberry growers alone, establishing the need for management for the statewide fruit industry, and growers can benefit from adopting physical exclusion and biological based pesticides. Our science-based management recommendations for this best improves overall sustainability of small fruit production in Minnesota.

PROJECT RESULTS USE AND DISSEMINATION
Our project has resulted in six peer-reviewed publications in scientific journals, eight academic presentations, over thirty talks to grower audiences and dozens of online newsletters, articles, and blog submissions, and a grower decision making tool. Grower recommendations are available on the FruitEdge website and archives on the UMN Extension Fruit and Vegetable News. Through this work, we have leveraged an additional $750,000 in federal funds to further develop sustainable production and pest management techniques for small fruit in Minnesota.

Subproject 10 completed: 08/31/2021
FINAL ABSTRACT

Sub-Project 11: Will Future Weather Favor Minnesota's Woody Invaders? - $514,325 TF

Peter Reich
U of M - Department of Forestry
220F Green Hall
1530 Cleveland Avenue North
St Paul, Minnesota 55108

Phone: (612) 624-4270
Email: preich@umn.edu
Web: https://www.forestecology.cfans.umn.edu

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
Our findings tell the story of how exotic honeysuckle and buckthorn have invaded Minnesota forests, how and why new areas are likely to be invaded in the future, and how we may be able to mitigate invasion using native tree species.

OVERALL PROJECT OUTCOME AND RESULTS
Glossy buckthorn, common buckthorn, tatarian honeysuckle, and morrow's honeysuckle are woody species that have been introduced to Minnesota forests from other continents. All four species frequently dominate forests and exclude native plant species. Warming temperatures and continued dispersal of these species are likely to significantly increase their abundance throughout Minnesota, especially in northern Minnesota. However, most effort by researchers and managers alike has been given to reactive measures against invasion instead of increased understanding of invasion processes and/or preventative measures. This project evaluated the climate sensitivity of these four invasive species in a way that provides for more accurate threat assessment of each throughout the state and provides tools for Minnesotans to potentially slow invasion into new areas and protect Minnesota's forests. We analyzed growth rings of 274 trees to determine how quickly invasive species spread and characterize how native and invasive species have responded to past growing conditions. We found that growth rates of invasive buckthorn and honeysuckle are most similar to native cherries and ashes in southern Minnesota, but that the invasive species already are growing much faster than those native species in northern Minnesota. Within a forest, we found that buckthorn tended first to invade hilltops and subsequently spread to low-lying areas at a rate of 3-4m yr-1 (slower than honeysuckle, which spread at 6 m yr-1). We experimentally assessed 10 native species in addition to the four invaders to determine which are favored by changing temperature and rainfall patterns (i.e. their responses to future climate). We found invasive and more southern native species to be favored by warming

conditions in terms of their growth and survival, whereas more northern native species were often strongly disfavored. We established programs to detect current invasion at fine-scale spatial resolution and predict future invasion based on the findings above, and set up long-term experiments to test the ability of tree plantings to slow invasion into new areas.

PROJECT RESULTS USE AND DISSEMINATION
Results from this project were disseminated through multiple avenues, including conference presentations, journal articles, and popular media. Principally, dissemination efforts focused on academic journals. We have submitted one manuscript detailing results from Activity 2 for peer review. Three other manuscripts related to the project are in preparation and will be submitted during the spring of 2022. We are also collaborating with National Geographic for a feature on work supported by this grant, primarily results associated with Activity 2.

Subproject 11 completed: 12/31/2021
FINAL ABSTRACT

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

Subd. 08b Propagating Native Plants and Restoring Diverse Habitats - $495,000 TF

Ashley Brenke
Martin County Soil and Water Conservation District
923 N State St, Ste 110
Fairmont, MN 56031

Phone: (507) 235-6680
Email: ashley.martinswcd@gmail.com
Web: http://www.martinswcd.net

Appropriation Language
$495,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Martin County Soil and Water Conservation District for a cooperative 13-county effort by Blue Earth, Brown, Cottonwood, Crow Wing, Faribault, Freeborn, Jackson, Lake, Le Sueur, Martin, Nicollet, Waseca, and Watonwan Counties to protect and expand native forest and prairie habitat for species in greatest conservation need in four regions of the state through collection and propagation of local ecotype native plants, habitat restoration efforts, and educational outreach. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This project enhanced the number and variety of native plant species on sites across the state of Minnesota. By working with a variety of partners, we were able to reach citizens from the border of Iowa up to Lake Superior, and teach many people about the importance of native habitats.

OVERALL PROJECT OUTCOME AND RESULTS
Minnesota is blessed to have a variety of habitats all across the state. The Thirteen Counties project focused on improving those diverse habitats by restoring uncommon native plant species. This had a secondary benefit of also providing habitat for other at-risk species. Local sourced species were chosen for planting that matched the growing conditions on the restoration site. Species selection was made depending on local

species availability and the characteristics of the sites.

Plant materials were collected locally from species that have little or no presence in restorations. Over 50,000 plants were propagated of 50 different species. Prior to establishing new native plant species on site, invasive species sometimes had to be removed. Restorations occurred on over 15 different sites across the state. Funds were directly used on sites in 4 different counties and technical assistance was provided to projects in 2 additional counties. While projects did not occur in 7 of the counties, project participants still heard updates about grant progress at regional meetings in southcentral Minnesota. The degree of invasive species removal varied from site to site. Some of the invasive species removed during this project were Common Tansy and Japanese Barberry. Resilient native species, such as Grass Leaved Goldenrod, were planted in place of the invasive species with the goal of being able to out-compete the invasive species long term. In Cottonwood County, for example, invasive buckthorn was removed and replaced with local dogwood shrubs.

Martin SWCD and project partners reached over 700 people (volunteers, students, etc.) through direct interaction at planting events and workshops. Thousands more were reached through social media, newsletters, radio, and local newspapers. Over 20 workshops and trainings were held as well. Some of the workshops were hands-on activities in the field, where others were more general topics in a classroom that focused on the difference between native and invasive species. Martin SWCD staff was able to share the knowledge they have gained about plant propagation from previous projects with other Southern Minnesota counties and with project partners at Crow Wing and Lake County SWCDs. The education transferred from experienced SWCD staff to new SWCD staff will be invaluable for years to come.

The most important achievement of this project is the number of people who learned more about habitats native to their region of the state. Individuals will take this knowledge and work on promoting and protecting native species in their own backyard, and pass it on for future generations to learn.

PROJECT RESULTS USE AND DISSEMINATION
Activities under this project were disseminated using a variety of different methods. Restoration sites were shown on Facebook as well as in videos on YouTube. Project information was also shared with numerous school classes, local elected Boards, volunteer organizations (Rotary Club, etc.), conservation clubs and at County Fairs. This project work was also covered in local newsletters and websites of the partner Soil and Water Conservation Districts. Over the years of the project, there were also a number of media outlets covering project work.

Project Completed: 06/30/2021
FINAL REPORT

Subd. 09 Land Acquisition for Habitat and Recreation

Subd. 09i Mesabi Trail Development Soudan to Ely - Phase II - $1,000,000 TF

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

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

Appropriation Language
$1,000,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the St. Louis and Lake Counties Regional Railroad Authority for the right-of-way acquisition, design, and construction of segments of the Mesabi Trail, totaling approximately seven miles between Soudan and Ely. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

SOUND BITE OF PROJECT OUTCOMES AND RESULTS
This segment, approximately 3 miles, of the Mesabi Trail starting from Highway 169 underpass to County Road 88 has been completed. We were able to construct the trail on portions of the former railroad grade, however, we ran into many road blocks from landowners that wouldn't allow for the trail to be on their property. Several alternative routes were considered. Right-of-way, environmental permitting, trail design, engineering and construction were completed with the best available route for this paved segment of the Mesabi Trail. We also came across old culverts needing replacement and were able to complete the project within our budget.

OVERALL PROJECT OUTCOME AND RESULTS
Completing the Mesabi Trail segment from the Highway 169 underpass to County Road 88 required the following analysis criteria and steps: route alternatives analysis; historic/cultural resource; social, economic and environmental effects; agency coordination; reports, notices and hearings; wetland delineation and mitigation; and final outcome. Four alternative routes were considered and evaluated, with the best final route determined by the above analysis. There were many delays encountered after selecting the route, namely right-of-way acquisitions. Originally, we were looking to use the abandoned railroad grade for the majority of this trail segment. However, many landowners owned parcels along the grade not allowing for easements. We again needed to adjust our trail route and moved approximately 1.0 mile to be along the Highway 169 right-of-way. This in turn, needed further environmental wetland, impact evaluations and engineering. In the end, approximately 18 acres through 22 parcels were acquired with easements, fee title, lands that the Regional Railroad Authority purchased and Limited Use Permits required to be alongside the highway right-of-way. All were purchased with non-ENRTF funds. Other items not anticipated were two culverts needing replacement as they were deteriorating and required adequate water flow away from the trail and other landowner's properties. Construction of the trail, COVID and personnel were other setbacks on completing this segment. With these unanticipated events, we were able to complete this trail project under budget. This segment of the Mesabi Trail near Ely, MN will be enjoyed by outdoor recreationalists for many years to come and are another segment closer to completing the continuous path of the Mesabi Trail from Grand Rapids to Ely.

PROJECT RESULTS USE AND DISSEMINATION
This trail segment was discussed at a public meeting held for another segment of trail, known as "Camp Lake Road to Highway 1/169 Underpass," and received recognition in the Ely Echo News. This trail segment has also been presented at local gatherings such as Ely Rotary, Ely City Council, Morse Township Board of Commissioners, Ely Chamber of Commerce, Ely Economic Development Authority and Visit Ely Convention & Visitors Bureau. Mesabi Trail news and updates are provided through a variety of media, marketing and publications. Web site is: Mesabitrail.com.

Project Completed: 12/31/2022
FINAL REPORT