Environment and Natural Resources Trust Fund
2014 Request for Proposals (RFP)

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Project Title:

Healthy Prairies: Seed Storage, Beneficial Microbes, and Adaptation

Category: F. Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Total Project Budget: $ 695,000

Proposed Project Time Period for the Funding Requested: 3 Years, July 2014 - June 2017

Other Non-State Funds: $ 0

Summary:

We will collect and preserve germplasm of plants throughout Minnesotas prairie region, study microbial effects on them, and discover the scale of local adaptation and rate of ongoing adaptation.

Name: Ruth Shaw

Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

MP: 0613-2-055-proposa
Budget: 0613-2-055-bud
Qual: 0613-2-055-qualifi
Map: 0613-2-055-map-H
Resolution:
List:

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

Capacity Readiness Leverage Employment TOTAL

PROJECT TITLE: Healthy prairies: Seed storage, beneficial microbes, and adaptation

I. PROJECT STATEMENT

With the **GOALS** of preserving prairie plant diversity in Minnesota and promoting restoration of thriving prairies, we propose to accomplish the following **OUTCOMES**:

1. collection and preservation of germplasm of prairie species from throughout the prairie region of MN,
2. determination of microbes that promote the health of prairie plants,
3. discovery of the scale of local adaptation for diverse prairie plant species, and
4. evaluation of the adaptive capacity of prairie plant populations.

This work will provide fundamental information necessary to the state's efforts to establish both scientifically sound and economically feasible practices for prairie restoration.

Background: Since European settlement, the once vast expanses of MN prairie, approximately 18 million acres, have been diminished to small remnants totaling about 235,000 acres. Similarly, the once tremendous genetic diversity within each of the many species that typify prairie has been drastically reduced. Consequently, remnant populations are subject to severe inbreeding, which reduces the robustness of plants and can cause further population decline. Increasingly, society recognizes that prairies play critically important roles, such as:

- stable, resiliant plant communities
- habitat for diverse wildlife, including pollinators
- maintenance of water quality
- roadside stabilization
- sustainable harvest of biomass for fuel production
- sources of novel plant products for local industries, e.g. cosmetics. Leadplant is one of several showing promise in recent research.

In addion to needs for these crucial ecological services, the goal of preserving the natural beauty of prairies for future generations is spurring efforts for extensive prairie restoration. However, such large-scale prairie restorations face daunting challenges.

Restorations that will thrive require large quantities of seeds adapted to the environment in which they will grow. Even small remnants of prairie retain valuable genetic resources. Protection of these remaining genetic resources now can ensure that this genetic variation will be available as germplasm for massive restorations now, for future adaptation to climate change, and for human uses yet to be discovered. Minnesota's prairie plants have been adapting to their local climates and soils since the glaciers receded 14,000 years ago. Beneficial microbes adapted along with the plants. However, climate is now changing at a rate that calls into question the capacity of plants to adapt and raises concerns about losses of native plant species and invasion of noxious weeds.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: Collection and conservation of 480 populations of prairie plants. Budget: $125,000

We will collect seeds of at least 40 species characteristic of MN prairies for conservation and research, sampling moist and dry habitats in at least 3 populations in each of the 4 ecologically defined subsections of MN prairie, and taking care both to obtain genetically representative samples for each population and to avoid depleting seed input to the site. Samples will be stored in the state-of-the-art facility at the USDA National Center for Genetic Resources Preservation in Fort Collins, CO, *at no cost* to the state of MN. NCGRP scientists have honed techniques to maximize seed viability over long-term storage; facilities and staff there cannot feasibly be duplicated in MN. Seed resources will not be given to Colorado or other entity; the state of MN and this project retain ownership of all seeds. Staff at the seed facility will assess viability and study the longevity of seeds. This genetic material will be made available to MN seed producers at nominal cost.

Outcome	Completion Date
1. A lasting archive of a well-designed sample of prairie genetic diversity.	Oct 2016
2. Measures of the initial viability of seed samples.	Dec 2016
3. Estimates of the longevity of the stored seeds.	Dec 2017

Activity 2: Microbial aids to plant health. **Budget: $150,000**

Recent studies show that plants may need help from microbes as they are moved to new locations and adapt to conditions there. We will characterize the beneficial microbes that live with plants in their natural habitats and determine how the microbes can be managed for natural soil health and to enhance restoration success. We will also assess how disease causing microbes might limit plant health and adaptation.

Outcome	Completion Date
1. Determine the composition of beneficial microbial communities and how these microbial species differ across seed source populations.	Jan 2016
2. Evaluate the extent to which the most common pathogenic and beneficial microbes are locally adapted.	Aug 2017

Activity 3: The scale of local adaptation. **Budget: $225,000**

To rigorously evaluate the scale and degree of local adaptation, we will focus on 6 species that typify MN prairie, including iconic prairie grasses and legumes. We will plant seeds from all sampled populations at sites within 3 of the subsections of MN's Prairie Parkland Province. We will economize significantly by using existing UM Research and Outreach Centers. We will monitor survival and growth of plants from each sampled population at each site and determine the relationship between plant survival and geographic location, and soil moisture differences across a local site.

Outcome	Completion Date
1. Experiments to evaluate effects of seed source distance on establishment and long-term success of prairie plants in restorations.	Aug 2017
2. Evaluation, for each species, of the relationship between early performance of plants and distance to source as well as habitat characteristics.	Aug 2017

Activity 4: Adaptive capacity of prairie populations. **Budget: $195,000**

The rate at which plants adapt to changes in climate and any other aspects of environment depends on the amount of genetic variation available for adaptation. We will assess the available genetic variation by conducting quantitative genetic studies of plant characteristics involved in adaptation; for example, leaf thickness is often important for adaptation to drought. These studies will focus on 2 species that are also represented in the local adaptation experiment (Activity 3).

Outcome	Completion Date
1. Prediction of rates of adaptation based on genetic variation and natural selection.	June 2017

III. PROJECT STRATEGY

A. Project Team: UMN faculty, Drs. Shaw, Wyse, May. Partners (not budgeted for NRTF): UMN-TC faculty Galatowitsch, Moeller, Tiffin; UM-D faculty Etterson; The Nature Conservancy. USDA NCGRP has agreed to contribute in-kind services without charge.

B. Timeline Requirements: 3 yr are required for evaluation of local adaptation of plants through the period of establishment, as also for the quantitative genetic studies of potential for ongoing adaptation. The microbial studies (isolation and identification of microbes, evaluation of their effects on plants) also require at least 3 yr.

C. Long-Term Strategy and Future Funding Needs: We plan to build this project over at least 10 yr, expanding to collect more plant species in more locations within MN, to evaluate microbial effects through more of the plants' life-cycle, and to continue evaluation of the field experiments. Thus, we anticipate requesting further funding from LCCMR. This project will benefit from seed collection infrastructure being developed with current NSF funding to Shaw and Etterson, from May's currently NSF-funded microbial research, and from Wyse's current research into useful products of native prairie plants. Funding of this proposal for the labor-intensive establishment of study plots will be leveraged into further funding from NSF. Such an expanded project would yield even greater insights, also providing educational and outreach programs to the MN public.

2014 Detailed Project Budget

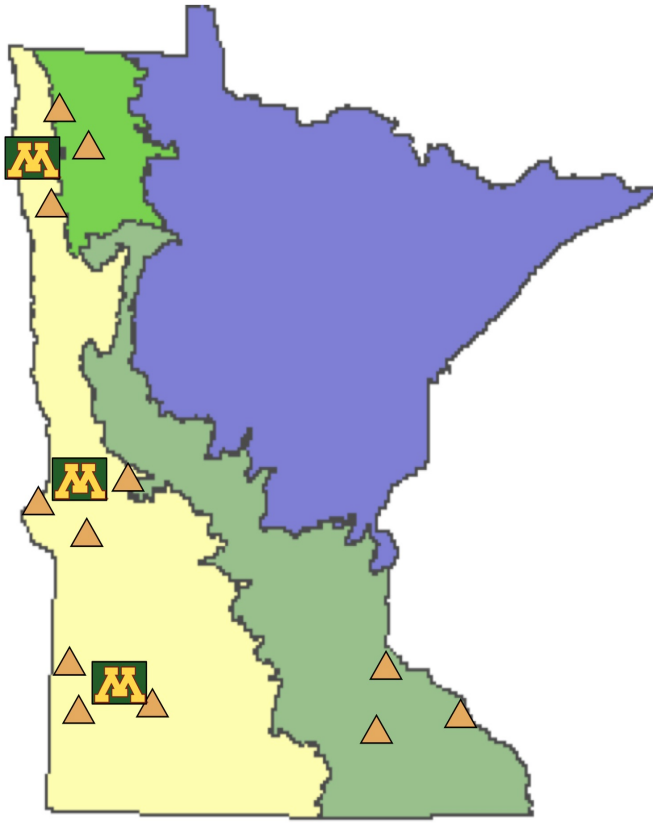
Project Title: Healthy prairies: Seed storage, beneficial microbes, and adaptation

IV. TOTAL ENRTF REQUEST BUDGET - 3 years

BUDGET ITEM	AMOUNT
Personnel: Dr. Ruth Shaw, Professor: One month summer salary per year is requested for supervision of, as well as participation in, the seed sampling and field experiments investigating local adaptation component of the project. 76% salary, 24% benefits.	$ 48,000
Personnel: Dr. Georgiana May, Professor: One month summer salary per year is requested for supervision of, as well as participation in, the studies of microbial interactions with prairie plants and their role in plant fitness.76% salary, 24% benefits.	$ 43,000
Personnel: Dr. Donald Wyse, Professor, will participate without salary.	$ -
Personnel: 1 Postdoctoral Associate will be recruited for fulltime participation in this research. 83% salary, 17% benefits.	$ 158,000
Personnel: Two graduate students will be paid for work on the project for one academic semester (52% salary, 48% benefits) and one summer (82% salary, 18% benefits) each year.	$ 161,000
Personnel: Four undergraduates will be paid to work on the project for 10 weeks each summer (93% salary, 7% benefits).	$ 62,000
Personnel: Two civil service people will work halftime for the duration of the project (73% salary, 27% benefits). In addition, funds are budgeted to cover the costs of labor to maintain the experiments by civil service people based at each of the ROCs.	$ 191,000
Equipment/Tools/Supplies: Supplies - Greenhouse and field supplies include materials for gathering seeds; pots, soil, and tags for establishing plants in the greenhouse; and stakes for delineating plots in the field. Lab supplies include petri dishes, media and reagents.	$ 9,000
Travel: Travel within MN to sites for collecting seeds and to locations of experimental plots and lodging. Budgeted amount based on distances to collecting and experimental sites and standard rates for the University of Minnesota.	$ 6,000
Additional Budget Items: Lab services for sequencing of microbial genomes (Bacterial sequencing: 400 plant samples, with 50 samples per sequencing lane, $1600 per lane: (400/50)*1600 = $12800. Fungal sequencing: 360 plant samples are expected to yield about 1000 fungi, $4 to sequence each = $4000. Altogether, $17,000 for sequencing)	$ 17,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 695,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period:	$ -	
Other State $ Being Applied to Project During Project Period:	$ -	
In-kind Services During Project Period: Storage of seed samples at the USDA facility, NCGRP, and	$ -	secured
Remaining $ from Current ENRTF Appropriation (if applicable):	$ -	
Funding History: NSF funding to Etterson and Shaw for collection of seeds throughout the midwest, $600,000; NSF funding to May for study of hyperdiverse endophytic fungi and their functions,	$ 1,680,000	secured

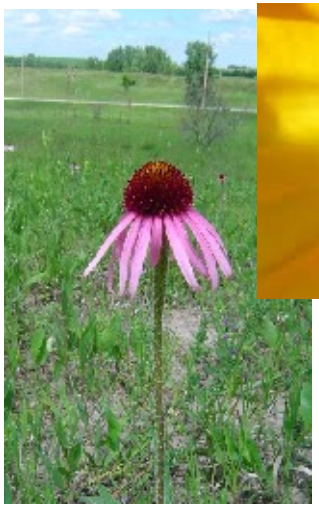


Evaluation sites
– UM Outreach stations

Collection sites

Plant-associated microbes
nutrient uptake
N-fixation
protection against disease

Soil microbes
decomposition
mineralization



Project Manager Qualifications: Ruth Geyer Shaw
Professor, Department of Ecology, Evolution, and Behavior, University of Minnesota-TC

Education and Research Leaves:

B.A. Biology	1976	Oberlin College, Oberlin, Ohio;
Ph.D. Botany and Genetics	1983	Duke University, N. Carolina
Post-doctoral in Genetics	1984-1986	University of Washington, NIH Fellow
Sabbatical	1995-6	Edinburgh University
Guggenheim Fellow	2002-3	Université de Montpellier, France

Throughout my career, my research has addressed fundamental questions regarding adaptation in native plant populations and has also yielded guidance for managing impacts of human disturbance, including climate change, introduction of invasive plants, and the fragmentation of populations into small remnants. In my 20 yr at UM, I have mentored graduate students' experimental studies of adaptation in prairie plant populations, and for 13 yr I have led UM's participation in an NSF-funded long-term experimental study investigating the evolutionary consequences of severe fragmentation of prairie populations of purple coneflower, *Echinacea angustifolia* (collaboration with Dr. S. Wagenius of the Chicago Botanic Garden, see http://echinacea.umn.edu). Among the key results of these studies are demonstration of: degree of local adaptation to present-day habitats and limits to rates of adaptation to climate change in partridge pea, *Chamaecrista fasciculata*[1,2], dramatic reduction in seed production of progeny from crosses between prairie plant populations[3], large differences in survival and fecundity among remnant populations[4], and exceptionally severe inbreeding depression affecting growth and fitness in purple conflower[5,6] (selected references in leading scientific journals below). Moreover, my colleagues and I have recently developed an approach for analyzing data on individual survival and fecundity, the central measures of adaptation[4,5]. This new approach, which provides far more precise inferences about adaptation than previously possible, will be crucially important to the success of the proposed research.

[1]Etterson, J. R. and R. G. Shaw. 2001. Constraint to adaptive evolution in response to global warming. Science 294: 151-154. [2]Davis, M.B. and R. G. Shaw. 2001. Range shifts and adaptive responses to quaternary climate change. Science 292: 673-679. [3]Heiser, D.A. and R.G. Shaw. 2006. The fitness effects of outcrossing in *Calylophus serrulatus*, a permanent translocation heterozygote. Evolution 60:64-76. [4]Geyer, C. J., S. Wagenius, and R. G. Shaw. 2007. Aster models for life history analysis. Biometrika, 94: 415-426. [5]Shaw, R.G., et al. 2008. Unifying life history analyses for inference of fitness and population growth. American Naturalist 172: E35-E47. [6]Wagenius, S., et al. 2010. Biparental inbreeding and inter-remnant mating in a perennial prairie plant: fitness consequences for progeny in their first eight years. Evolution 64:761-771.

Organization Description: The mission of the Department of Ecology, Evolution and Behavior is to advance and disseminate knowledge in these fields through excellence in theoretical, experimental, and field research; undergraduate and graduate education; scholarly activities; and outreach. The integration of this knowledge across levels of biological complexity is a prerequisite to addressing many of the biological and environmental challenges facing society. http://www.cbs.umn.edu/eeb/