Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2017 LCCMR Work Plan

Date of Submission: September 14, 2016

Date of Next Status Update Report: January 1, 2018

Date of Work Plan Approval:

Project Completion Date: June 30, 2020

Does this submission include an amendment request? no

PROJECT TITLE: Optimizing the Nutrition of Roadside Plants for Pollinators

Project Manager: Emilie Snell-Rood

Organization: University of Minnesota

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Location: Anoka, Becker, Benton, Big Stone, Blue Earth, Brown, Carver, Cass, Chippewa, Chisago, Clay, Clearwater, Cottonwood, Crow Wing, Dakota, Dodge, Douglas, Faribault, Fillmore, Freeborn, Goodhue, Grant, Hennepin, Houston, Hubbard, Isanti, Jackson, Kandiyohi, Lac qui Parle, Le Sueur, Lincoln, Lyon, McLeod, Mahnomen, Martin, Meeker, Mower, Murray, Nicollet, Nobles, Norman, Olmsted, Otter Tail, Pipestone, Pope, Ramsey, Redwood, Renville, Rice, Rock, Scott, Sherburne, Sibley, Stearns, Steele, Stevens, Swift, Todd, Traverse, Wabasha, Wadena, Waseca, Washington, Watonwan, Wilkin, Winona, Wright, Yellow Medicine

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$815,000**
	Amount Spent:	**$0**
	Balance:	**$815,000**

Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 08a

Appropriation Language:
$815,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with the Departments of Agriculture, Natural Resources, and Transportation and the Board of Water and Soil Resources to produce site-specific recommendations for roadside plantings in Minnesota to maximize the nutritional health of native bees and monarch butterflies that rely on roadside habitat corridors. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: ***Optimizing the nutrition of roadside plants for pollinators***

II. PROJECT STATEMENT:

Pollinators have suffered steep declines over the last two decades. We rely on bees for pollination of over 70% of crops; however, some species have declined by 90% over the last two decades. Monarch butterflies, which are so loved by the American public that they would spend over $4 billion to save them, have declined more than 80% over the last 20 years. From the White House's recent "Pollinator Research Action Plan" to state-specific legislation from Minnesota to California, there are increasing calls for pollinator conservation, including for 7 million acres of new pollinator habitat. One promising direction is the use of roadside habitat as a source of pollinator larval and adult resources. Within Minnesota alone, there are over a million acres of roadside habitat.

This research will result in site-specific recommendations for roadside plantings in Minnesota to maximize the health of bees and butterflies that rely on such habitats as conservation corridors. While roadsides are promising pollinator habitat, there is a concern they may act as ecological sinks, which attract pollinators, but result in declines in pollinator health. For instance, plants along roadsides can accumulate sodium from salt runoff. Sodium is a potent attractant for many animals, and while it is an important micronutrient, they can feed on it to the point of toxicity. Nitrogen also accumulates on roadsides, potentially attracting animals with protein-poor diets to areas that also suffer from heavy metal buildup from brake and tire wear. Pesticide spillover from adjacent agricultural fields may additionally limit the quality of roadside habitats. Because different plants accumulate chemicals to different degrees, this research aims to develop recommendations for plantings for various road use intensities that optimize the value of roadside milkweed for monarchs and flower pollen and nectar for bees.

The first activity of this work will survey roadside plants and pollinators at 50 sites across Minnesota, measuring the nitrogen, sodium, heavy metal, and insecticide content of leaves, nectar, and pollen from four species of plants favored by pollinators. The second activity of this work will use data from the roadside surveys to rear monarchs and bumblebees in nutritional conditions simulating high, medium, and low use road intensities to determine levels at which nutrients and heavy metals become toxic. The third activity of this work will use controlled field manipulations to determine how plants of different families accumulate nutrients and heavy metals under conditions simulating high, medium, and low road use intensity. Taken together, these data will speak to which species of plants should be prioritized in the restoration of roadsides for pollinators.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *[January 1, 2018]***:**

Project Status as of *[July 1, 2018]***:**

Project Status as of *[January 1, 2019]***:**

Project Status as of *[July 1, 2019]***:**

Project Status as of *[January 1, 2020]***:**

Overall Project Outcomes and Results [June 30, 2020]**:**

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: *Survey of roadside plants and pollinators*
Description:

The first aim of this research is to document the nutrient content of roadside plants and pollinators along Minnesota roadways. Drawing from an existing network of roadside sites randomly distributed across non-forested areas of the state, we will survey 50 sites across varying degrees of road use intensity and adjacent agricultural use. Plant samples will be taken of four focal native species commonly used by pollinators, including

common milkweed (Apocynaceae: *Asclepias syriaca*), gray-headed coneflower (Asteraceae: *Ratibida pinnata*), bee balm (Lamiaceae: *Monarda fistulosa*), and showy tick trefoil (Fabaceae: *Desmodium canadense*). Importantly, these plants are in bloom in July (when sampling will occur) and are commonly found along Minnesota roadsides. We will measure the nutrient and heavy metal composition of leaves, pollen and nectar of these samples, including nitrogen, phosphorus, sodium, nickel, zinc, cadmium, and lead. A subset of milkweed samples will be used to measure pesticide content.

At each site we will additionally sample pollinators using these roadsides to test whether a nutrient and heavy metal signature can be seen in insect tissue. We will focus our pollinator sampling efforts on larval monarchs (*Danaus plexippus*), a common native bumblebee that flies in July (*Bombus impatiens*), and an easily identifiable native bee with a smaller foraging range (*Agapostemon virescens*). At each site, we will take data on additional factors known to affect nutrient and heavy metal deposition, including roadside slope, wind direction, and adjacent areas where traffic changes speed. We predict that the nitrogen, sodium, and heavy metal content of plant leaves, nectar and pollen, along with insect tissue itself, will increase as road use intensity increases.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 381,500
Amount Spent: $ 0
Balance: $ 381,500

Outcome	Completion Date
Collection of roadside plants, soil, and pollinators across two field seasons	Aug. 2018
Nutrient, heavy metal & pesticide content of roadside plants and soils	Dec 2018
Measurement of pollinator nutrient, heavy metal content	Dec 2018

Activity 1 Status as of *[January 1, 2018]***:**

Activity 1 Status as of *[July 1, 2018]***:**

Activity 1 Status as of *[January 1, 2019]***:**

Final Report Summary:

ACTIVITY 2: *Pollinator health in different nutrient conditions*
Description:

The second aim of this work seeks to determine levels at which nutrients and heavy metals become harmful to pollinators. Data from Activity 1 will be used to parameterize diets representative of low, medium, and high road use intensity for both monarchs and bumblebees.

We will use *Bombus impatiens* as a model bumblebee system. Nitrogen, sodium, nickel, and zinc will be manipulated in pollen balls of 60 queens, mimicking concentrations measured in pollen in activity 1. We will measure development time and body size of 10 offspring per queen. *Danaus plexippus* (monarchs) will be reared on milkweed grown in conditions meant to simulate low, medium, and high road use intensity. Leaves will be harvested from field plots for rearing of monarchs under controlled lab conditions where only nutrition is manipulated. We will measure survival, development time, and adult body size for at least 30 individuals per treatment.

Data on size and development time will address whether roadside nutrient levels are harmful to pollinators. We predict that growth parameters will be highest at the medium-level road use intensity, and lowest at the high level. Additionally, we will compare levels of pesticides measured in Activity 1 to levels found in other studies to be toxic in bumblebees and monarchs.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 191,500
Amount Spent: $ 0
Balance: $ 191,500

Outcome	Completion Date
Determine optimal nutrient conditions for developing bumblebees	Dec 2018
Determine optimal nutrient conditions for developing monarchs	Dec 2018

Activity 2 Status as of *[July 1, 2018]***:**

Activity 2 Status as of *[January 1, 2019]***:**

Activity 2 Status as of *[July 1, 2019]***:**

Final Report Summary:

ACTIVITY 3: *Plant nutrient status and pollinator preferences*
Description:

Given that different plants concentrate nutrients to different degrees, the final aim of this research is to determine which plant species would maximize pollinator health along roadsides. We will work with the DNR, MnDoT, and the Minnesota Board of Soil and Water Resources to choose 12 focal plant species with established success in roadside restorations in Minnesota. We will focus on four plant families favored by pollinators: Asteraceae, Fabaceae, Apocynaceae, and Laminaceae, choosing three different species within each family to make generalizations about how a given plant family reacts to different simulated roadside conditions.

We will grow 12 different plant species at three sites of varying soil conditions at the Cedar Creek Ecosystem Science Reserve. At each site, we will simulate the different nutrient and heavy metal conditions at low, medium, and high road use intensities, adding nitrogen, sodium, nickel and zinc to the soil at three different times. Following the experiment, heavy metal addition will be mitigated with the application of phosphorus and organic matter.

Three replicate plants per site per species will be sampled for leaves, pollen and nectar, for nutrient and heavy metal analyses. We will additionally work with the Cedar Creek internship program to survey pollinators in these plots, measuring the abundance of pollinating bees for least 10 time points during flowering. As expected for Activity 1, we predict that the nutrient and heavy metal content of plants will increase as simulated road use intensity increases**.** As pollinators tend to be attracted to high sodium and high nitrogen resources, but often fail to discriminate against heavy metal presence, we predict that pollinators will favor the high road use intensity plots.

Finally, with data from all three activities in hand, we will meet with the DNR, MnDoT, and the Minnesota Board of Soil and Water Resources to discuss optimal roadside plantings for different road use intensities.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 242,000
Amount Spent: $ 0
Balance: $ 242,000

Outcome	Completion Date
Measure nutrients in different plant species in controlled conditions	Dec 2019
Determine pollinator preference for different plant nutrient contents	Sept 2019
Recommendations for roadside plantings to maximize pollinator health	June 2020

Activity 3 Status as of *[July 1, 2019]***:**

Activity 3 Status as of *[January 1, 2020]***:**

Activity 3 Status as of *[July 1, 2020]***:**

Final Report Summary:

V. DISSEMINATION:
Description:

Scientific publications. All results will published as open access papers in peer-reviewed scientific journals such as Ecology, Proceedings of the National Academy of Sciences, or PLoS One. We expect at least 2 publications to arise from each activity.

Publically available data. All data will be publically available, either in databases such as DRYAD (http://www.datadryad.org/) and/or through the Department of Natural Resources Observation Database.

Collaborative meetings with relevant agencies and the development of management best practices. Throughout the project planning, and as data become available, we will talk with the DNR, MnDot, and Board of Water and Soil Resources through email, conference calls, and in person meetings. Such discussions have already fruitfully led to the sampling strategy for Activity 1. Future meetings will further refine the proposed methods in addition to discussing the broader management implications of the findings. We will consider what the survey data (Activity 1), pollinator rearing (Activity 2), and plant manipulations (Activity 3) mean for pollinators along roadsides – are some plants more likely than others to maximize the health of pollinators along roads? Are some road use intensities more or less likely to compromise the health of pollinators feeding there? How might the present results interact with other management considerations such as traffic death or mowing? We aim to develop site-specific recommendations that can be used to guide roadside management for pollinators.

Status as of *[January 1, 2018]***:**

Status as of *[July 1, 2018]***:**

Status as of *[January 1, 2019]***:**

Status as of *[July 1, 2019]***:**

Status as of *[January 1, 2020]***:**

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:
A. Preliminary ENRTF Budget Overview:
***This section represents an overview of the preliminary budget at the start of the project. It will be reconciled with actual expenditures at the time of the final report.**

Budget Category	$ Amount	Overview Explanation
Personnel:	$50,000 $21,000 $7,500 $23,000 $167,000	• Emilie Snell-Rood, project manager: 12% FTE for years 2 and 3, 4% FTE Year 1 – oversee and coordinate entire project • Clay Carter, Asst Prof: 4% FTE for 3 years – oversee all nectar and pollen analyses • Karen Oberhauser, Prof: 4% FTE for year 1 – oversee and advise on all monarch rearing and milkweed analysis • Elizabeth Borer, Prof: 4% FTE for 3 years – oversee and coordinate plant nutrient manipulations at Cedar Creek • Postdoctoral Associate: 100% FTE for years 2 and 375% FTE year 1 – Run all nutrient field manipulations, coordinate data analysis and writing

	$297,000 $38,000 $67,000	• Two graduate research assistants: 50% FTE for 3 years – Run all bee and monarch rearing experiments, assist with plant collection and manipulations • Two undergraduate research assistants, 92% FTE & 23% FTE for 2 years; Field assistants, help with rearing and sample processing • Lab technician: 100% FTE for 1 year, 25% FTE for year 2 -- run all roadside surveys and sample processing
Professional/Technical/Service Contracts:	$8000	• The Department of Natural Resources will provide valuable consulting and advice across 9 total meetings (3 per year, 2 hrs/meeting, 4 people/meeting)
Equipment/Tools/Supplies:	$6000 $6000 $3000	• Supplies for collecting and processing plants and pollinators (Activity 1): vials, dry ice, cooler, paper bags, forceps, safety vests, weather gauge, meter sticks, capillary tubes, microcentrifuge tubes, gloves, paintbrushes, clipboards and writing utensils • Supplies for rearing monarchs and bees (Activity 2): queen bees from Koppert, CO2 tanks, plastic rearing containers, paper towels, ethanol, bleach, pollen, honey, sugar, sharpies, bee labels, super glue, plastic bags, chemical reagents (NaCl, NiCl2, ZnCl2) • Supplies for field manipulations of plants and pollinator observations (Activity 3): field guides, NaCl, NiCl2, ZnCl2, nitrogen fertilizer, watering cans, plant seeds, soil amendments, clipboards
Printing:	$6000	• Open access publications (2 papers per activity)
Travel Expenses in MN:	$17,000	• Travel to 50 roadside sites for sampling plants and pollinators in Activity 1 (approximately 3000 miles over a 4-month period over two field seasons, includes lodging and meal allowance for technician and field assistant) • Travel to Cedar Creek field site for plot manipulations in Activity 3 and plant collection for rearing in Activity 2
Other:	$98,500	• Plant, soil and insect samples for measurement of nitrogen, sodium and heavy metals content ($20/sample). A subset of plant samples will be assayed for insecticides ($300/sample). Activity 1 includes approx 3 species across 50 sites (nectar, pollen, leaves, N = 3/sp/site). Activity 3 includes 12 species across at least 3 subplots at 3 sites (N = 3/sp/treatment)
TOTAL ENRTF BUDGET:	**$815,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: Grad students = 3 (2 people half time for 3 years), Snell-Rood = 0.375 (1.5 mos. for 3 years), Oberhauser = 0.042 (0.5 mos. for 1 year), Borer = 0.126 (0.5 mos. for 3 years), Carter = 0.126 (0.5 mos. for 3 years), Postdoc = 2.75 (1 person full time for 2.75 years), technician = 1.25 (1 full time for 1 year and second field season), Undergrads = 1.75 (1

person @ half time during the academic year and 2 people at full time during the summer - for 2 years): total = **9.5**

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
In kind services	$372,000	$0	
Indirect costs associated with this proposal			
	$	$	
State			
	$	$	
TOTAL OTHER FUNDS:	**$372,000**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners:

Partners receiving ENRTF funding

- Emilie Snell-Rood, Associate Professor, University of Minnesota, Project leader, $50,000
- Karen Oberhauser, Professor, University of Minnesota, Oversee monarch work, $7.500
- Elizabeth Borer, Professor, University of Minnesota, Oversee nutrient manipulations, $23,000
- Clay Carter, Assistant Professor, University of Minnesota, Oversee nectar measurements, $21,000
- Graduate student assistants, University of Minnesota, Run rearing experiments, $297,000
- Postodoctoral researcher, University of Minnesota, Run field manipulations, $167,000
- Lab Technician, University of Minnesota, Roadside surveys, $67,000
- Undergraduate assistants, University of Minnesota, Run site surveys, $38,500
- Crystal Boyd, Department of Natural Resources, advise on site selection, design, conclusions, $8,000

Partners NOT receiving ENRTF funding

- Dan Cariveau, Assistant Professor, University of Minnesota, advise on bee surveys
- Marla Spivak, Professor, University of Minnesota, Oversee bee rearing
- Dan Shaw, Minnesota Board of Water and Soil Resources, advise on plant selection
- Ken Graeve, Minnesota Dept. of Transportation, advise on plant selection

B. Project Impact and Long-term Strategy:

The final outcome of this project will be recommendations for roadside plantings to maximize pollinator health. For example, preliminary data show that milkweed can accumulate very high levels of sodium, suggesting plantings along less intensely used rural roads may be ideal. Datasets will be made publically available on the digital repository "DRYAD" and the DNR observation database; publications will be open access. Throughout the project planning, and as data become available, we will talk with the DNR, MnDoT, and Board of Water and Soil Resources through email, conference calls, and in person meetings. At the conclusion of the data collection, we will discuss the broader management implications of the findings. We will consider what the survey data (Activity 1), pollinator rearing (Activity 2), and plant manipulations (Activity 3) mean for pollinators along roadsides – are some plants more likely than others to maximize the health of pollinators along roads? Are some road use intensities more or less likely to compromise the health of pollinators feeding there? How might the present results interact with other management considerations such as traffic death or mowing? We will develop site-specific recommendations that can be used to guide roadside management for pollinators. We will additionally

communicate these findings to all relevant stakeholders. In doing so, this research will contribute to the development and use of roadsides as habitat for monarchs and native bees.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
Funds supplied from the Office of the Vice President for Research (University of Minnesota) that funded this project during its first two years (spent by 2013). Resulted in publication: Snell-Rood et al. 2014 PNAS	2011-2013	$28,000
		$
		$

VIII. REPORTING REQUIREMENTS:

- **The project is for 3 years, will begin on 07/01/17, and end on 06/30/20.**
- **Periodic project status update reports will be submitted** *[January 1]* **and** *[July 1]* **of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2020**.

IX. VISUAL COMPONENT or MAP(S):

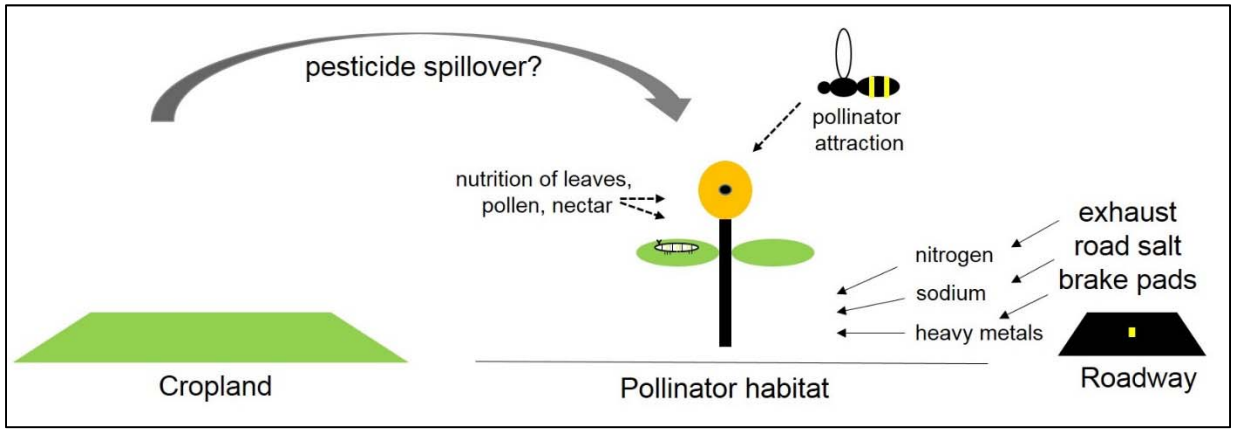

Figure 1. ***Research overview***. Some elements of road runoff such as nitrogen and sodium may attract pollinators to roadsides where toxins such as pesticides and heavy metals may additionally be present. This research addresses the nutrition of roadside plants through roadside surveys, developmental manipulations of monarchs and bumblebees, and plant trials to optimize which species to plant along roadways of different use profiles.

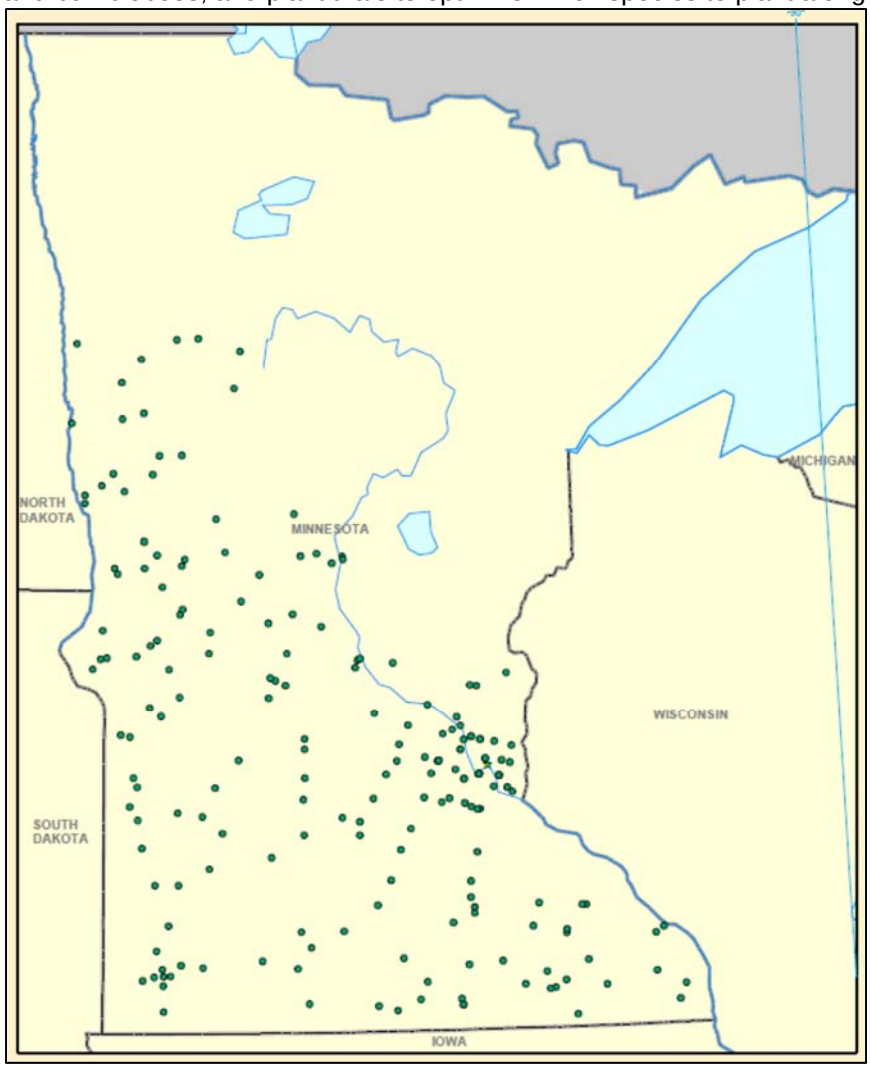

Figure 2. ***Roadside sites***. Activity 1 of this research will focus on 50 roadside sites drawn from an existing network of sites (shown here). These sites represent a random sample of sites within prairie and open habitats within 200 miles of the Twin Cities. We will build on existing data for these sites, which will include two field seasons of surveys of milkweed and monarchs. Over 50% of these sites contain milkweed. The sites include a mixture of road use intensities and adjacent land use (>50% agriculture).

Environment and Natural Resources Trust Fund
M.L. 2017 Project Budget

Project Title: Optimizing the Nutrition of Roadside Plants for Pollinators
Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 08a
Project Manager: Emilie Snell-Rood
Organization: University of Minnesota
M.L. 2017 ENRTF Appropriation: $15,000
Project Length and Completion Date: 3 years, June 30, 2020
Date of Report: September 14, 2016

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Survey of roadside plants and pollinators***			***Pollinator health w/ nutritional conditions***			***Plant nutrient status and pollinator***				
Personnel (Wages and Benefits)	$287,000	$0	$287,000	$182,500	$0	$182,500	$201,000	$0	$201,000		$670,500
Emilie Snell-Rood, project manager: $50,000 (75% salary, 25% benefits), 4% FTE in Year 1, 12% FTE for years 2 & 3											
Clay Carter, Asst Prof: $21,000 (75% salary, 25% benefits), 4% FTE for 3 years											
Karen Oberhauser, Prof: $7,500 (75% salary, 25% benefits), 4% FTE for 1 year											
Elizabeth Borer, Prof: $23,000 (75% salary, 25% benefits), 4% FTE for 3 years											
Postdoctoral Associate: $167,000 (82% salary, 18% benefits), 75% FTE in Year 1, 100% FTE in years 2 & 3											
Two graduate research assistants: $297,000 (52% salary, 48% benefits during academic year; 85% salary, 15% benefits during summer), 50% FTE for 3 years											
Two undergraduate research assistants, $38,000, one 50% time during academic year and 2 full-time in the summer (100% salary, 0% benefits) 92% FTE & 23% FTE for 2 years											
Lab technician: $67,000 (79% salary, 21% benefits), 100% FTE year 1, 25% FTE for year 2											
Professional/Technical/Service Contracts	$4,000	$0	$4,000				$4,000	$0	$4,000		$8,000
The Department of Natural Resources will provide valuable consulting and advice across 9 total meetings (3 per year, 2 hrs/meeting, 4 people/meeting)											
Equipment/Tools/Supplies	$6,000	$0	$6,000	$6,000	$0	$6,000	$3,000	$0	$3,000		$15,000

Supplies for rearing monarchs and bees (Activity 2): queen bees from Koppert, CO2 tanks, plastic rearing containers, paper towels, ethanol, bleach, pollen, honey, sugar, sharpies, bee labels, super glue, plastic bags, chemical reagents (NaCl, NiCl2, ZnCl2)											
Supplies for collecting and processing plants and pollinators (Acitivity 1 and 3): vials, dry ice, cooler, field microscopes, paper bags, forceps, safety vests, weather gauge, meter sticks, capillary tubes, microcentrifuge tubes, gloves, paintbrushes, clipboards and writing utensils, drierite											
Supplies for field manipulations of plants and pollinator observations (Activity 3): field guides, NaCl, NiCl2, ZnCl2, nitrogen fertilizer, watering cans, plant seeds, soil amendments, clipboards											
Capital Expenditures Over $5,000											
None											
Fee Title Acquisition											
NA											
Easement Acquisition											
NA											
Professional Services for Acquisition											
NA											
Printing	$2,000	$0	$2,000	$2,000	$0	$2,000	$2,000	$0	$2,000		$6,000
Open-access publications											
Travel expenses in Minnesota	$14,000	$0	$14,000	$1,000	$0	$1,000	$2,000	$0	$2,000		$17,000
Travel to 50 roadside sites for sampling plants and pollinators in Activity 1 (approximately 3000 miles over 4 month period for two field seasons, includes lodging and meal allowance for technician and field assistant); travel to field site for plot manipulations in Activity 3 and plant collection for monarch rearing Activity 2											
Other	$68,500	$0	$68,500				$30,000	$0	$30,000		$98,500
Plant, soil and insect samples for measurement of nitrogen, sodium and heavy metals content ($20/sample). A subset of plant samples will be assayed for insecticides ($300/sample). Activity 1 includes approx 3 species across 50 sites (nectar, pollen, leaves, N = 3/sp/site). Activity 3 includes 12 species across at least 3 subplots at 3 sites (N = 3/sp/treatment)											
COLUMN TOTAL	**$381,500**	**$0**	**$381,500**	**$191,500**	**$0**	**$191,500**	**$242,000**	**$0**	**$242,000**		$815,000