

2014 Project Abstract

For the Period Ending June 30, 2017

PROJECT TITLE: Assessing species vulnerability to climate change using phenology

PROJECT MANAGER: Rebecca Montgomery

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2014, Chp. 226, Sec. 2, Subd. 05e

APPROPRIATION AMOUNT: 175,000\$

AMOUNT SPENT: 175,000\$

AMOUNT REMAINING: 0\$

Overall Project Outcomes and Results

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

Project Results Use and Dissemination

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

manage a Facebook page (Minnesota Phenology Network) on which we share results and create online community.



Environment and Natural Resources Trust Fund (ENRTF) M.L. 2014 Work Plan Final Report

Date of Report: 22 September 2017
Final Report
Date of Work Plan Approval: 4 June 2014
Project Completion Date: 30 June 2017
Does this submission include an amendment request? No

PROJECT TITLE: Assessing species vulnerability to climate change using phenology

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Location: Statewide

Total ENRTF Project Budget:	ENRTF Appropriation:	\$175,000
	Amount Spent:	\$175,000
	Balance:	\$ 0

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 05e

Appropriation Language:

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

I. PROJECT TITLE: Assessing species vulnerability to climate change using phenology

II. PROJECT STATEMENT:

Global climate change has the potential to profoundly impact natural resources and associated human communities worldwide. Phenology, the timing of seasonal biological events such as budburst, flowering, bird migration and leaf coloring, has provided the most compelling evidence to date that plants and animals are responding to changes in climate across the globe. Indeed the Intergovernmental Panel on Climate Change recognized that “phenology ... is perhaps the simplest process by which to track changes in the ecology of species in response to climate change.” Across Minnesota temperatures have risen by ~2 degrees F over the last 50 years and are projected to rise by ~7-9 degrees F by the end of the century. There is a critical need to understand how our natural resources are currently responding to climate change and develop tools for projecting natural resource responses into the future. Phenology provides an excellent and tested indicator of climate change response.

Why is phenology an indicator of climate change? Many plants and animals use temperature as a cue for leafing, flowering, spawning or migration. When the climate changes so does the timing of these life cycle events. But not all species change the same way. For example, caterpillars that overwinter in Minnesota emerge when it gets warm in spring. However, migratory songbirds that winter in the tropics don't know when it's warm in MN. Instead, they follow the change in the length of the day to determine when to return to MN. Thus, with climate change, the birds return at the same time each year but the caterpillars that feed the songbird young emerge earlier and earlier. Such a mismatch in timing is responsible for songbird declines in England and Europe. We don't know if such mismatches are happening in Minnesota.

Change in phenology can have major impacts on natural resources. Longer growing seasons can increase forest productivity but early leafing and flowering can also expose plants to devastating frost damage. In 2012, apples flowered early in response to warm March temperatures. Then, a normal April frost caused major damage to apple flowers drastically reducing apple crop yields. Minnesota's native tree species such as oaks, maples and aspens showed a similar response. However, unlike commercial species such as apple, limited data on native species phenology inhibits our ability to anticipate and manage change.

The major objectives of this project include:

- identify plant and animal species that are vulnerable to climate change
- develop a network of observers and sites to monitor phenology into the future
- provide data to natural resource managers for developing adaptive strategies that sustain environmental quality in a changing climate.

To achieve these objectives we will analyze historical records of phenology to understand past trends in timing of biological events, predict future trends using models based on historical data, collect new data on phenology to test models and provide continued monitoring into the future.

Historical phenology records are a valuable and endangered Minnesota resource, yet they are scattered, piecemeal across the state and at risk. These records are a critical resource for understanding natural resource changes already occurring. For example, a record from St. Paul, MN (AC Hodson 1941-1991) shows that aspen trees are leafing almost two weeks earlier now than in the past. Historical data could be lost if it is not digitized, documented and stored in a permanent database. We will locate, digitize and analyze handwritten historical records to examine whether and how phenology has changed in recent years. We will use these data to model the relationship between climate and phenology. These data will show us how plant and animals in Minnesota are responding to climate change and identify species that exhibit responses that make them vulnerable to various factors such as insect outbreak, early or late season frost, decreased productivity. They also provide a baseline against which to measure changes in the future. Models of the relationship between climate and phenology will allow us to predict future trends.

Phenology resonates strongly with the public. Who has not noticed when the leaves emerge or turn color, when the crocuses and daffodils bloom? We will harness this enthusiasm to *develop a new statewide observer network to monitor phenology* of a core set of species across the state's major ecoregions. Phenology observers will be recruited through partnerships with environmental learning centers, nature centers, parks, natural areas, arboreta, schools and interested citizens. Observers will participate in face-to-face or online training and will enter data via an online data entry system already developed by the USA-National Phenology Network. New observations can be used to test models built with historical data and can build on and extend the historical record dataset.

New knowledge gained from this project will improve natural resource decision-making in a changing climate. Better understanding of natural resource changes associated with climate change in Minnesota will enhance adaptive management strategies that sustain productivity of MN forests; support plant pollination and reproduction; and maintain the integrity of wildlife and fisheries in the face of climate change.

III. PROJECT STATUS UPDATES:

Project Status as of: January 1, 2015

We have digitized six datasets for a total of 13,000 individual records of over 650 species of amphibians, reptiles, birds, butterflies, dragonflies, plants. This dataset is currently on a development webpage that will likely go live within the next two months. We have begun to outline the format and audience of the natural resource manager workshops. We have begun development of training manuals and on-line training materials as well as outreach to key groups for statewide training workshops that will recruit new observers.

Project Status as of: October 16, 2015

We continue to digitize datasets. The database is online and downloadable (https://www.usanpn.org/mnnpn/sites/www.usanpn.org.mnnpn/files/file/data_table_full.html). We are periodically updating the online version with new data as it is digitized. We have conducted preliminary analyses of the data to date. We continue to outline the format and audience of the natural resource manager workshops. In the process, it has become apparent that we will reach a much larger audience by shifting towards presenting to natural resource managers and participating in existing and planned workshops on topics for which phenology is pertinent (e.g. climate change adaptation). We are scheduled on two broader events in the month of October. We continue development of training manuals and on-line training materials as well as outreach to key groups for statewide training workshops that will recruit new observers.

Project Status as of: May 1, 2016

We continue to digitize datasets. The database is online and downloadable (<https://www.usanpn.org/mnnpn/datatable>). We are periodically updating the online version with new data as it is digitized. We have conducted preliminary analyses of the data to date. We developed visualization tools and are tracking requests to download the data (<https://www.usanpn.org/mnnpn/datasets>). We continue to offer workshops and consultations for new observers and natural resource management groups. We continue to develop training manuals and on-line training materials as well as outreach to key groups for statewide training workshops that will recruit new observers.

Project Status as of: August 8, 2016

We continue to digitize datasets. The database is online and downloadable (<https://www.usanpn.org/mnnpn/datatable>). We are periodically updating the online version with new data as it is digitized. We have conducted preliminary analyses of the data to date. We developed visualization tools and are tracking requests to download the data (<https://www.usanpn.org/mnnpn/datasets>). We continue to offer

workshops and consultations for new observers and natural resource management groups. We continue to develop training manuals and on-line training materials as well as outreach to key groups for statewide training workshops that will recruit new observers. We have partnered with a new project Backyard Phenology led by artist Christine Bauemler and PI Montgomery. We are using this to reach new audiences for trainings and outreach. We have begun development of online learning modules for training.

Amendment Request: August 30, 2016

I request several amendments to the budget.

1. I request a shift \$20,654 from the *project coordinator (Chris Buyarski)* to a *graduate research assistant* supported at 25% time. As we've begun analysis of the historical data, we have realized that the nature of the analysis requires Ph.D. student level experience beyond that of the project coordinator.
2. I request to shift \$2500 from *travel* to *printing*. Our travel expenses have been less than expected due to use of environmental learning centers and University of Minnesota field stations for housing and meals. In our training and natural resource manager workshops we've found that a color printed version of the 'How to Observe' handbook from *Nature's Notebook* with modifications for the Minnesota Phenology Network provides a critical guide for workshop participants. In post workshop assessments, project participants state it is an invaluable tool for monitoring and for understanding data collected using *Nature's Notebook*. Our original printing run was 100. I'd like to use project funds to print ~150 additional copies for upcoming 2016-2017 training and manager workshops. Printing in color with a coil binding costs ~\$18/booklet using university printing services. We also look at Kinko's (\$41) and Staples (\$25).
3. I request a shift \$4000 of funds from *Professional/Technical/Service Contracts* to *undergraduate student salary*. These funds were originally designated to support a web developer. I have found a number of promising computer science students wanting more experience in web design and programming. They are able to provide services needed at a much lower cost than professional developers and thus we get more for less in terms of outcomes and deliverables.

Amendment Approved by LCCMR 8/30/2016

Project Status as of: February 21, 2017

We continue to digitize datasets. The database is online and downloadable (<https://www.usanpn.org/mnnpn/datatable>). We are periodically updating the online version with new data as it is digitized. We conducting in-depth analyses of the data this spring using statistical modeling as well as a process based model developed by a French research group. We are tracking requests to download the data (<https://www.usanpn.org/mnnpn/datasets>) which have increased through time. We continue to offer workshops and consultations for new observers and natural resource management groups. We continue to develop training manuals and on-line training materials as well as outreach to key groups for statewide training workshops that will recruit new observers. We continue our partnership with Backyard Phenology led by artist Christine Bauemler and PI Montgomery. We are using this to reach new audiences for trainings and outreach. We have developed three online learning modules for training with up to eight forthcoming.

Amendment Request: June 8, 2017

I request one amendment to the budget. I request to shift \$1500 from *personnel* to *travel*. We were invited to conduct training workshops at the White Earth Math and Summer Academy, Circle of Life Academy, White Earth, MN. The audience will be 50 Native American youth in, 4th - 8th grade and 6 teachers from 3 school districts. This will advance outcomes of Activity 2 to train a statewide network of observers and diversify our network. The Circle of Life Academy runs from Jun 12-Jun 30, 2017 so we request this amendment by Jun 12, 2017.

Amendment Approved by LCCMR 6/9/2017

Overall Project Outcomes and Results:

Understanding how natural resources are responding to climate change and developing tools for projecting responses into the future represent critical needs for environment and natural resource management in Minnesota. Phenology, the timing of biological events such as budburst, flowering and bird migration, provides an excellent and tested indicator of climate change response. The objectives of this project included: identify species vulnerable to climate change, develop a network of observers to monitor phenology into the future, provide data to natural resource managers for developing adaptive strategies that sustain environmental quality in a changing climate. To achieve these objectives we analyzed historical records of phenology to understand past trends and trained citizen scientists to collect new data to test models and provide continued monitoring into the future. In total we digitized over 44,595 historical observations from around the state of Minnesota. We performed >25 statewide training seminars (~700 participants) and created online training materials and a website. The number of observers entering phenological data into *Nature's Notebook* went from 140 in 2015 to 1150 today. Minnesota now has the second most phenology observers by state, only surpassed by California. Observers come from all parts of the state (n=108 Northwest MN, 193 Northeastern MN, 59 Central MN, 85 Southern MN, and 703 in the Twin-cities Metro area). The growth in new observations has increased between 22-51% per year since the start of the project. Combining historical and current datasets yielded a total of 865,816 phenological observations. Our work is significant as one of the largest regional datasets documenting change in nature's cycles and seasons. The data is publicly available for natural resource managers and scientists to use in decision-making. Examining phenological trends through time, we've found a number of species that earlier spring phenology and later fall phenology as predicted under climate change. Among notable animals, Sandhill Crane, Northern White Shoveler, American White Pelican and Eastern Towhee are arriving significantly earlier. For plants, apple, bur oak, American elm, quaking aspen, beaked hazel and red pine all show significantly earlier budburst. For many of these, events are happening 7-9 days earlier in than in the 1940s. On-going analyses in a Ph.D. thesis will highlight species that could be at risk in a changing climate and thus guide policy and decision-making.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Digitize and analyze historical phenology observations to predict species at risk

Description: We know of at least ten localities ranging from Rochester to Finland with phenology datasets longer than 25 years. These represent daily to weekly observations on >50 plant and animal species for a total of >500,000 individual observations. Some of these are in digital format but others are not. A key challenge for this activity will be to create a standardized database of plant and animal taxa with standardized phenological events or phases. Since there are many animals and plants that differ in life history this is a challenge. Project staff will develop the database structure in consultation with others that have conducted similar projects in other US states. We will then work with several of the naturalists who have collected the data to begin data entry/digitization. This will provide beta testing of the database by phenology experts. After beta testing, we will use University of Minnesota students to digitize additional datasets. The first step in our analysis process will be to examine trends in phenological events through time. The second step will be to model the relationship between climate and phenology. Climate data for locations and years for which we have data will be downloaded from the State Climatologist website and supplemented as necessary from other sources. Climate and phenology datasets will be linked and process-based models that use climate variables to predict phenology will be fit to the data. Both of these analyses will allow us to identify plants and animals that are vulnerable to climate change and provide a baseline against which to compare changes in the future. Our results will be used to develop collaborative workshops for natural resource managers to determine where, when and how phenological data can inform management as well as identify data gaps that could be filled in the future.

Summary Budget Information for Activity 1:**ENRTF Budget: \$ 78882****Amount Spent: \$ 78882****Balance: \$ 0****Activity Completion Date: June 30, 2017**

Outcome	Completion Date	Budget
1. Online searchable database of >500,000 historical phenological observations	June 2015	\$41056
2. Five statewide workshops for natural resources managers communicating our results and developing management strategies that sustain environmental quality in a changing climate	June 2016	\$19937
3. Webpages depicting phenology of vulnerable species – updated quarterly with new data from Activity 2 and hosted by the University of Minnesota	June 2017	\$20913

Activity Status as of: January 1, 2015

We have spent the first six months of the project working largely on outcome 1 as the latter outcomes depend on having a database of standardized and compiled data. We hired an undergraduate student, Paul Lanctot, who is majoring in computer science to work on the online database. He has developed a MySQL database as well as documentation materials for future database/site administrators. The database will be served via the Minnesota Phenology Network website. Currently, we have a development site and are testing the functionality of the served product. We obtained written copies of phenology observation summaries of Larry Weber covering ~18 years and 200 species. These were checked for data quality and digitized. We obtained digital versions of datasets collected by John Latimer (Grand Rapids, MN), Alec Hodson (St. Paul, MN), John Weber (Nevis, MN), Ron Kuehn (East Bethel, MN) and Dallas Hudson (Nevis, MN). We also included our own dataset (East Bethel, MN). To date, the database contains 13,000 records of over 650 species of amphibians, reptiles, birds, butterflies, dragonflies, plants. Most of the records are from the last 30 years although the Hodson dataset dates to 1940. We are working with the Eloise Butler Wildflower garden and the Hennepin County Libraries to get a dataset from the garden that covers the 1960s and 70s and will fill a time gap in the database. We have been in contact with the director of the sustainable forests education cooperative to collaborate on organizing and delivering the workshops for natural resource managers (outcome 2). Working as a project team with our web master (Paul Lanctot) we are in the design phase for the webpages associated with outcome 3.

Activity Status as of: October 16, 2015

We continue to digitize datasets. The pace has slowed because we started with those most simple to incorporate into our database (e.g. those that were already digital). We are now transcribing written records as well as processing datasets that require information extraction to fit our format. We have started analyses of the data. Currently we have available and have started to analyze data on 41 unique amphibians/reptiles, 280 birds, 114 butterflies, 30 dragonflies, 722 plants, 1 mammal, 3 insects, 2 arachnida, 2 moths, 7 damselflies, 42 insects and 12 moths. For plants we have 6,260 data points in timing of first flowering in Carlton county, 944 points for first flowering in Hubbard county, 306 points for Ramsey county. The Ramsey county data has 14 tree/shrub species that go back to 1941 (oldest data). To date we have data from five MN counties: Carlton (7,842 datapoints), Hubbard (5,845), Itasca (427), Ramsey (714), Sherburne (2459). For those records with long enough time trends (n=10), we find 31 species to be changing to earlier dates, 54 to later dates, and 613 unchanged. Some example graphics of trends in phenology through time are posted and described on our website (<https://www.usanpn.org/mnnpn/data>). The Ramsey County dataset of trees and shrubs shows 6 of 14 showing earlier spring phenophases. Specifically, apple, bur oak, and American elm show earlier budburst and apple and silver maple show earlier flowering in spring. These events are happening 7-9 days earlier in than in the 1940s.

Activity Status as of: May 1, 2016

We continue to digitize datasets. The pace has slowed because we started with those most simple to incorporate into our database (e.g. those that were already digital). We are now transcribing written records as well as processing datasets that require information extraction to fit our format. We recently received new digitized records from the Eloise Butler Wildflower Garden that will add data from the 50s and 60s to our dataset.

Activity Status as of: August 8, 2016

We continue to digitize datasets. The pace has slowed because we started with those most simple to incorporate into our database (e.g. those that were already digital). We are now transcribing written records as well as processing datasets that require information extraction to fit our format. We recently received new digitized records from the Eloise Butler Wildflower Garden that will add data from the 50s and 60s to our dataset. We have recruited a graduate student at the UMN who will work on further analysis of the dataset.

Activity Status as of: February 15, 2017

We continue to digitize datasets. The Eloise Butler record is ~1/2 finished and we have several undergraduate students focused on finishing this digitization by May. We recently acquired a dataset from DNR Wildlife organized by Jack Moody including up to 15 phenophases from 10-12 sites from 1979-1991. We have started to digitize this dataset. Claudia Nanninga (graduate student) is analyzing trends through time as well as developing process-based models that can be used to predict future responses of Minnesota species.

Final Report Summary:

Outcome 1: Since the last reporting period, we completed the digitization of the Eloise Butler record that contained 11,966 observations on 441 species during the years 1955-2001. In total we digitized over 44,595 observations around the state of Minnesota, these data are freely accessible to the public via an online database (<https://mnpn.usanpn.org/dataset-download-form>). To date, this dataset has been downloaded 17 times. In addition, *Nature's Notebook* currently houses 821,221 of observations from Minnesota that are in a standardized format collected since 2008. These data are also freely accessible to the public online (<https://www.usanpn.org/results/data>). That brings the total online searchable data to 865,816 phenological observations in Minnesota on 1546 species and 84 different phenological stages were monitored.

Outcome 2: We performed both in person presentations and workshops for resource managers. These were aimed at showing how to monitor phenology and why it can be a tool for management strategy. The list of trainings is below.

Buyarski, C. (2015). DNR Park Naturalist Annual Meeting: An Introduction to the Minnesota Phenology Network. Tettegouche State Park, Silver Bay, MN. October 28th, 2015. 46 attendees

Carlson, S. Montgomery, R. Buyarski, C. (2017). Phenology: Monitoring Seasonal Change. Rydell National Wildlife Refuge, Erskine, MN. March 9, 2017. 25 attendees.

Carlson, S. Swan, P. Buyarski, C. (2017). Aldo Leopold Phenology Workshop, MN Valley Wildlife Refuge. Bloomington, MN. March 3, 2017. 20 attendees.

Montgomery, R., Buyarski, C. (2016). Science Saturday: Using *Nature's Notebook* for phenology observations and citizen science. Soudan Underground Mine State Park, Tower, MN. May 28th, 2016. 11 attendees

We also presented workshops two years in a row at the Gathering Partners in Natural Resources Conference sponsored by Minnesota Master Naturalist program, Minnesota Forestry Association, and Minnesota Phenology Network.

Originally, we'd planned to conduct workshops that used results to discuss management strategies with natural resource managers. The dataset continued to grow throughout the project and proved more difficult to analyze than expected. In addition, natural resource managers expressed interest in learning more about phenology in general before thinking about applications to management. Finally, most of the interest from the natural resource community came from parks and protected areas that were interested in monitoring for climate change as well as public engagement. As such our workshops for Activity 1 and our trainings for Activity 2 ended up having considerable overlap.

Outcome 3: As stated earlier, our dataset of historical observations is available online. In addition, we created a visualization tool for exploring those data (mnpn.usanpn.org/datasets). Given the size of the dataset we continue to work on analysis, which has become part of a Ph.D. thesis at the University of Minnesota. We are limiting our current analysis to observations of species and events with more than 10 years of data. This results in 1567 observations of species and phenological events for our analysis. These data include: 14 unique amphibians/reptiles, 134 birds, 81 butterflies/moths, 30 dragonflies, 590 plants, 3 mammals, 4 other insects and 1 spider.

We have data from 9 Minnesota counties: Anoka, Carlton, Hennepin, Hubbard, Itasca, Marshall, Ramsey, Sherburne and Washington. For those records with long enough time trends ($n=1567$), 194 (12%) were fall related phenological events, such as changing leaf color, leaf fall, and migratory animal behavior, while 88% were spring related events, such as leaf and flower budburst, and the arrival of migratory animals. Out of the 1,567 species/event combinations, 257 (16%) showed a significant change. Out of these 257 significant events, 29 (11%) were fall related changes, and 89% were spring or summer related. If plants and animals are shifting phenology in response to changes in Minnesota climate, we'd expect fall events to be getting later (e.g., later date of peak fall colors) and spring events to be getting earlier (e.g., earlier dates of budburst and flowering). The predicted response of summer events is less certain. Out of all significant fall phases, 66% were later as expected and 10 (34%) were earlier. Most of the earlier events were related to animal migrations, some to earlier leaf color (e.g. *A. saccharum* all leaves colored). For all significant spring phases (those occurring before Jun 20), 69% occurred earlier. Among notable animals, Sandhill Crane (Figure 1), Northern White Shoveler, American White Pelican and Eastern Towhee are arriving significantly earlier. In contrast, Red Headed Woodpecker, Eastern Meadowlark, Baltimore Oriole and Indigo Bunting appear to be arriving later. For plants, apple, bur oak, American elm, quaking aspen, beaked hazel and red pine all show significantly earlier budburst. For many of these, events are happening 7-9 days earlier in than in the 1940s. Of 52 species with significant changes in spring flowering, 75% were earlier as expected. These included apple and silver maple for trees and trout lilies, trilliums, marsh marigolds among other spring wildflowers. Notable among these is the Minnesota trout lily (Figure 2), Minnesota's only federally listed endangered plant species. This species has been observed at Eloise Butler Wildflower Garden and shows highly significant earlier flowering. Research in other areas suggests that those species that are able to track changing climate by shifting flowering phenology are more likely to maintain populations while those that don't shift show population declines. Some example graphs of change through time are depicted.

Figure 1. Sandhill crane arrival as a function of time. Ignore year in y-axis as statistical programs require a year for dates to sort properly.

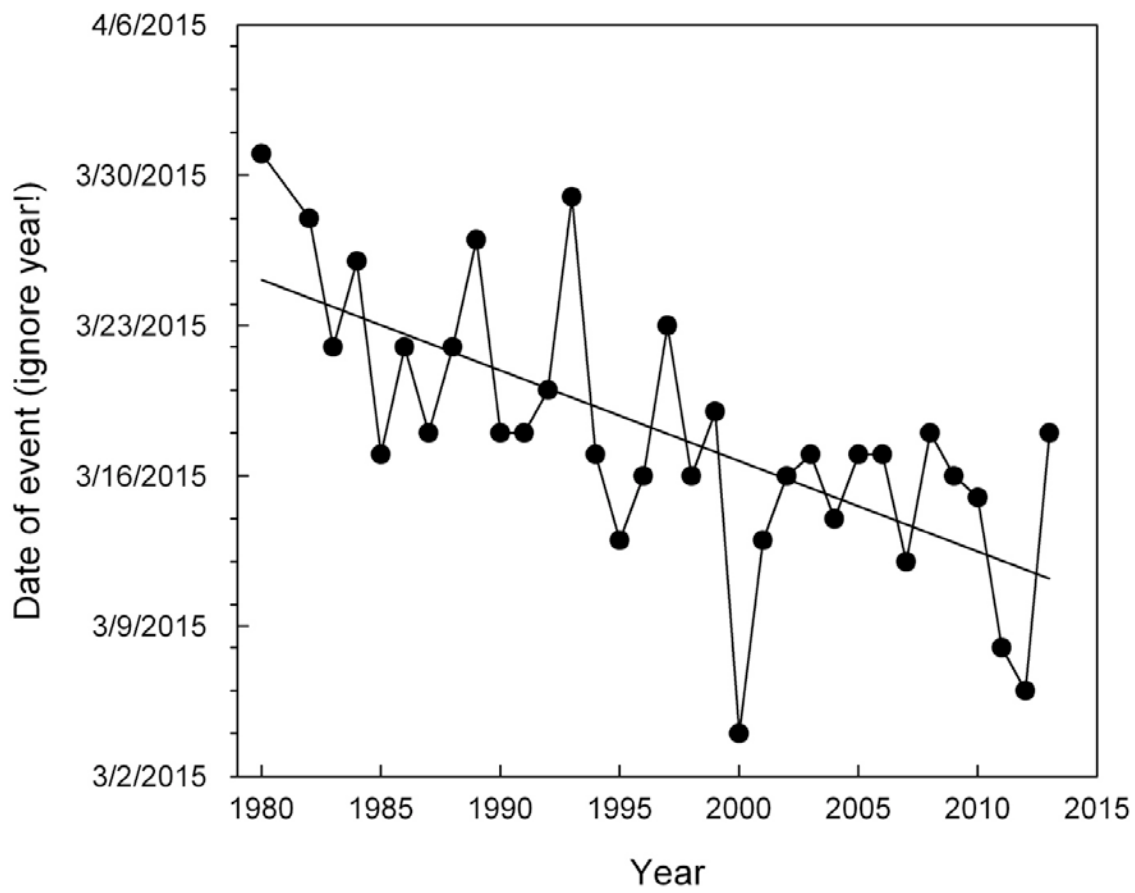
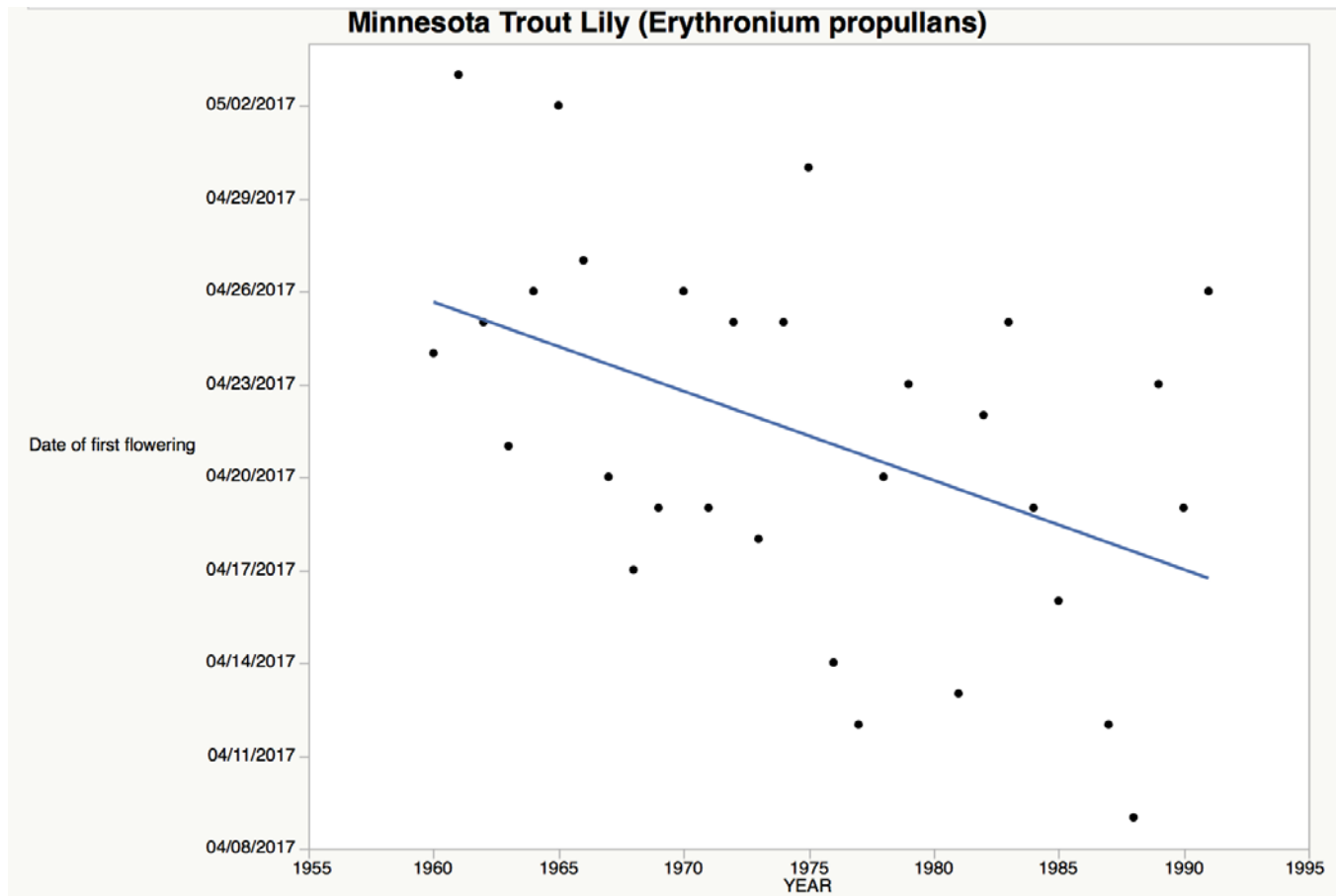


Figure 2. Minnesota Trout Lily (*Erythronium propullans*), federally listed endangered species. Ignore year in y-axis as statistical programs require a year for dates to sort properly.



ACTIVITY 2: Recruit and train a statewide network of observers to monitor vulnerable species

Description: We will collect new data on vulnerable species identified in Activity 1 as well as a set of common species by establishing observation sites statewide through partnerships with environmental learning centers, nature centers, parks, natural areas, arboreta, schools and interested citizens. Partnerships will be developed through formal and informal contacts depending on the partner. For example, we will approach nature centers directly to introduce the project and invite participation. Interested citizens will be recruited via three existing Facebook groups (Duluth Phenology Watch, Season Watch and the Minnesota Phenology Network), various phenology related radio programs that run throughout the state (e.g. KAXE in northern MN, WCCO in central MN), Master Naturalist and Master Gardner programs and other natural history related groups (e.g. Audubon Society, MN Native Plant Society). New observers will participate in face-to-face or online training. We have conducted pilot training sessions through other funding sources that were highly successful. Observers will be trained in protocols that are developed at the national level by the USA-National Phenology Network. They will enter data via an existing online data entry system through a Minnesota specific web portal that is also currently under development. New data will be used to validate and extend models of the relationship between climate and phenology and our assessments of species vulnerability.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 86256
Amount Spent: \$ 86256
Balance: \$ 0

Activity Completion Date: June 30, 2017

Outcome	Completion Date	Budget
1. Training manuals and on-line training materials developed	June 2015	\$25024
2. Statewide training workshops – at least 200 people trained	June 2016	\$30362
3. Educated and engaged partners with 50 observers in each ecoregion generating >30,000 observations per year	June 2017 and ongoing	\$25024
4. Combined online database of new and historical phenology observations	June 2017	\$12684

Activity Status as of: January 1, 2015

Stephan Carlson is leading development of training manuals and on-line materials. These will be a mix of locally generated content and nationally available resources via Nature’s Notebook, the USA-NPN program that provides the online platform for entry of new data. We have begun identification of key groups to target for statewide training workshops as well as drafting a letter of invitation to participate in workshops and the project as a whole.

Activity Status as of: October 16, 2015

We continue development of training manuals and on-line materials. As part of this effort, we conducted a competitive analysis of training materials from other groups to inform our training materials. We conducted a training session at the Gathering Partners of Natural Resources conference in May (sponsors included Minnesota Master Naturalist program, Minnesota Forestry Association, Minnesota Phenology Network). We trained 8 teachers as part of a Citizen Science for Teachers training program. We have scheduled several trainings with a planned promotion campaign for monitoring in Spring 2016.

Activity Status as of: May 1, 2016

We are focusing development of on-line training materials. We are starting to analyze MnPN submitted data via *Nature’s Notebook*. We have 53 registered *Nature’s Notebook* users that have associated themselves with the MnPN. In the two years of the project we have 2315 summarized observations of phenology that represent tens of thousands of individual daily or weekly observations. We will continue to recruit new observers in the last year of the project. We conducted the following workshops with more planned in late spring and summer.

October 29, 2015. MnPN fall phenology workshop; public; 35 participants; Minnesota Landscape Arboretum; MnPN; led workshop with Stephan Carlson.

November 14, 2015. Our changing seasons: A Phenology project for Minnesota, Monitoring Seasonal Change; Minnesota Naturalist’s Association (MNA) Annual Meeting; 25 attendees; Long Lake Conservation Center, Palisade, MN; led workshop with Stephan Carlson.

November 2015. Looking for a few good citizen scientists: Phenology brings climate change to your backyard! Poster presented at Extension’s 2015 Annual conference. Poster can be found at the following link: <http://hdl.handle.net/11299/175137>

February 12-14, 2016. Hosted Minnesota Phenology Network Annual Gathering; ~45 attendees; Wolf Ridge Environmental Learning Center, Finland, MN; offered two workshops on phenological monitoring one for lay people and one for K-12 teachers. Schedule of events can be found at the following link: <https://www.usanpn.org/mnnpn/sites/www.usanpn.org.mnnpn/files/u27803/PhenologyGatheringSchedule2016v3.pdf>

Activity Status as of: August 8, 2016

We continue to focus on development of on-line training materials. We are starting to analyze MnPN submitted data via *Nature’s Notebook*. We have 53 registered *Nature’s Notebook* users that have associated themselves

with the MnPN. We have 140 total users of *Nature's Notebook* in MN. In the two years of the project we have >250,000 individual daily or weekly observations. We will continue to recruit new observers in the last year of the project. We conducted the following workshops with more planned in late spring and summer.

May 14, 2016. Our changing seasons: A Phenology project for Minnesota, Monitoring Seasonal Change; Gathering Partners in Natural Resources Meeting; 25 workshop attendees; St. Mary's University, Winona, MN; led workshop with Stephan Carlson.

June 11, 2016. Worked with Backyard Phenology project to promote citizen science engagement in the Twin Cities through an art-science collaboration at Northern Spark 2016; Mill City Ruins/Guthrie Theater; >20,000 attendees.

July 30, 2016. Continued collaboration with Backyard Phenology. Led phenology walks and passed out getting started in *Nature's Notebook* flyers.

Our mailing list from our collaboration with Backyard Phenology is now ~200 persons. We plan to use this network for a series of workshops this winter and spring as part of the final year of the project.

Activity Status as of: February 21, 2017

Through our collaboration with Backyard Phenology's Climate Chaser we reached 1000s of people via the following events. Information on getting started with *Nature's Notebook* was provided as well as other material about connecting with the Minnesota Phenology Network.

7/11/16 Northern Spark
7/30/16 Summer4Play at Fort Snelling State Park
9/4/16 Minnesota State Fair
9/10/16 Monarch Festival – Festival de la Monarca
9/17/16 Frogtown Farm Harvest Festival
10/8/16 Mississippi River Valley National Wildlife Refuge
11/11/16 Minnesota Naturalist's Association

October 15, 2016 MnPN fall phenology workshop; public; 18 participants; Hubachek Wilderness Research Center; MnPN; led workshop with Stephan Carlson.

We have also created three of ~eight training and promotion videos. These three will be available on our website via YouTube by the end of the month. They include:

[An Introduction to Phenology](https://www.youtube.com/watch?v=3FsB3W6MStg) (<https://www.youtube.com/watch?v=3FsB3W6MStg>)

[Phenophases](https://www.youtube.com/watch?v=R7yxi797NGI) (<https://www.youtube.com/watch?v=R7yxi797NGI>)

[An Introduction to Nature's Notebook](https://www.youtube.com/watch?v=C6PDlxGn320&t=1s) (<https://www.youtube.com/watch?v=C6PDlxGn320&t=1s>) .

Additional videos will be produced and posted by the end of the project.

Final Report Summary:

1. Training materials are available online (<https://mnpn.usanpn.org/training-videos>), these include three training videos and an observation handbook. We had planned to create more videos about the basics

of using *Nature's Notebook* but learned that USA-NPN was creating these so we will link them to our website once finished.

2. We performed 23 statewide training seminars, and 680 participants have been trained during these programs. This does not include the hundreds of participants at large statewide conferences such as the Gathering Partners in Natural Resources yearly conference. A list of all training sessions and the number of participants are below. We also trained 34 teachers (7th-12th grade) on how to collect phenology data in the classroom as part of the science immersion class for science teachers affiliated with the University of Minnesota's Driven to Discover initiative.

Graf, S., & Carlson, S., (2017) Backyard Phenology: Interviews at the White Earth Indian Reservation, White Earth, MN. June. 65 participants.

Montgomery R., Baeumler, C., & Graf, S. (2017). Backyard Phenology: Interviews at the Saint Anthony Park Garden Tour, St. Paul, MN. June. 60 participants

Graf, S. (2017). Minnesota Phenology Network: Citizen Science Activities Day, 4-H Youth Exploring Leadership and Learning Out-loud! (YELLOW!) Conference. St. Paul, MN. June. 115 attendees.

Montgomery R., & Carlson, S., (2017) Phenology Webinar. Advanced MN Master Naturalist workshop held on line and at the St. Paul campus, Green Hall. April 5th, 24 attendees.

Carlson, S. Buyarski, C. Swan, P. (2017). Aldo Leopold Phenology Workshop, MN Valley Wildlife Refuge. Bloomington, MN. March 3, 2017. 20 attendees.

Montgomery R., Baeumler, C., Flick, K. & Carlson, S. (2016). Backyard Phenology: Interviews at the MN Naturalist Conference, Wolf Ridge, Finland, MN. November. 45 attendees

Carlson, S. & Montgomery R. (2016). Using Local Phenology to understand Climate Variable: North American Association for Environmental Education Conference, Madison WI., Invited presentation. October. 25 attendees

Montgomery R., & Carlson, S., (2016) Fall Phenology. Advanced MN Master Naturalist workshop held at the Hubachek Wilderness Research Center, Ely, MN. October. 18 attendees

Carlson, S. & Montgomery R. (2016). Backyard Phenology: Fort Snelling State Park Community Festival. Minneapolis, MN. Invited presentation. Bloomington, MN. July. 75 attendees

Montgomery R. & Carlson, S. (2016). Our changing seasons: Getting on Board for a Citizen Science Project for Minnesota. Gathering Partners Annual Conference, St Mary's Winona MN, Invited presentation. May. 24 attendees

Montgomery R. & Carlson, S. (2016) A Phenology project for Minnesota, Monitoring Seasonal Change. MN Phenology Network Annual Conference, Wolf Ridge, Finland, MN Invited presentation. Finland, MN. February. 60 attendees.

Montgomery R., Carlson, S., & Buyarski, C. (2015). Our changing seasons: A Phenology project for Minnesota, Monitoring Seasonal Change. MN Naturalist Association Annual Conference, Long Lake Conservation Center, Invited presentation. November. 45 attendees.

Montgomery R., Carlson, S., & Buyarski, C. (2015) Fall Phenology. Advanced MN Master Naturalist workshop held at the U of MN Arboretum, MN. October

Montgomery R., Carlson, S., & Buyarski, C. (2015). Looking for a few good citizen scientists: Phenology brings climate change to your backyard! Poster for Extension's, 2015 Annual conference. <http://hdl.handle.net/11299/175137>

Carlson, S. (2015) Naturalist Hike at Cedar Creek Ecosystem Scientific Reserve. Phenology Walk. MN Tourism Center, Extension, Bethel, MN. July. 12 participants on the walk

Latimer, J., Montgomery R., Carlson, S., & Buyarski, C. (2015) What's Happening in the Woods, Phenology Walk. MN Master Naturalist Association Annual Conference, Grand Rapids, MN. May

Montgomery R., Carlson, S., & Buyarski, C. (2015) Signs of the Seasons. What's happening in Phenology in Minnesota. MN Master Naturalist Association Annual Conference, Grand Rapids, MN. May

Montgomery R., & Carlson, S., (2015). Our Changing Seasons: A Citizen Science Phenology Project for Minnesota. MN Master Naturalist Association Annual Conference, Grand Rapids, MN. May

Carlson, S. (2015) Phenology Citizen Science Program, Presentation at Scandia, MN.

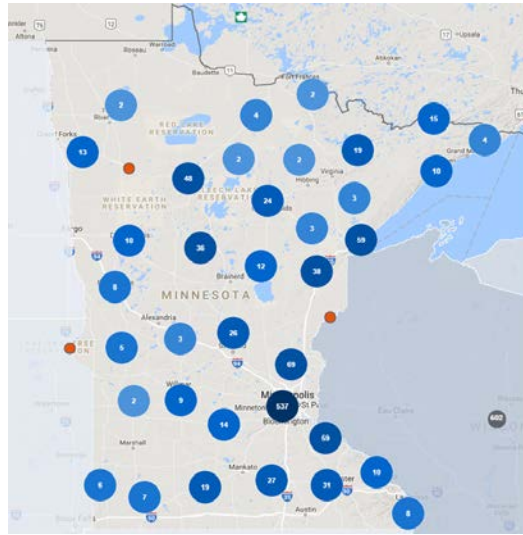
Carlson, S., Buyarski, C., & Weber, L. (2014). Advanced Master Naturalist course: "FALL Phenology", September 26. Cloquet Forestry Center, Cloquet, MN. 13 attendees.

Carlson, S., (2014). Advanced Master Naturalist course: "SPRING Phenology", Master Naturalist Annual Conference, presentation May 17. 25 attendees

Sagor, E., & Carlson, S., (2014). Advanced Master Naturalist course: "SPRING Phenology", Master Naturalist Annual Conference, May 16th 30 attendees

Sagor, E., Carlson, S., & Buyarski, C (2014). Advanced Master Naturalist course: "SPRING Phenology", April 25. U of MN, St Paul Campus St Paul, MN. 22 attendees.

3. Education and partnerships that were created during this project far surpassed our projected expectations. Over the course of three years, because of our outreach efforts, the number of observers entering phenological data into *Nature's Notebook* went from 140 in 2015 to 1150 today. To date, Minnesota now has the second most phenology observers by state, only being surpassed by California. The representation breakdown of these 1150 observers include 108 Northwest MN, 193 Northeastern MN, 59 Central MN, 85 Southern MN, and 703 in the Twin-cities Metro area (see map below).



- The combination of historical and current datasets from Minnesota has been completed in combination with our partnership with the USA-National Phenology Network. The combination of datasets has yielded 865,816 phenological observations going back as far as the year 1941. The growth in observations has also increased (between 22-51% per year) since the formation of this funded project (see Table 2 below)

Table 2: Number of phenological observations entered into *Natures Notebook's* online database from Minnesota by year.

2014	91,738
2015	138,936
2016	169,420
2017 (up to June 30 th 2017)	120,522

V. DISSEMINATION:

Description: Historical datasets will be shared through an online, searchable database to be developed as part of this project and served by the University of Minnesota and accessed through the Minnesota Phenology Network website hosted by the USA-NPN (<https://www.usanpn.org/mnnpn>). New data collected by citizen observers will be publicly available through Nature's Notebook, a program of the USA-NPN (https://www.usanpn.org/natures_notebook). Any training or workshop materials developed will be freely available via the Minnesota Phenology Network website. One of our project outcomes involves dissemination and presentation of results to natural resource professionals through workshops offered throughout the state. Presentation of the results will also occur through webinars (e.g. MN Woodland Advisors program), professional meetings (e.g. MN Society of American Foresters), and public events.

Status as of: January 1, 2015

No dissemination activities to report at this early stage of funding. The database should be 'live' by March 2015 and training materials available by our next status report.

Status as of: October 16, 2015

The database is now online and downloadable

(https://www.usanpn.org/mnnpn/sites/www.usanpn.org.mnnpn/files/file/data_table_full.html).

Status as of: May 1, 2016

Database and visualization of historical data are available (<https://www.usanpn.org/mnnpn/datasets>). We also have updated the website and starting providing profiles of Minnesota phenologists. We plan to develop a newsletter for summer 2016.

Status as of: August 8, 2016

Database and visualization of historical data are available (<https://www.usanpn.org/mnnpn/datasets>). We also have updated the website and starting providing profiles of Minnesota phenologists. We are working on a newsletter for summer 2016.

Status as of: February 21, 2017

We also have updated the website. We have developed a newsletter to be published quarterly. We are developing training videos for users and will complement these with online videos and content of key results. We are working with UMN Extension, My Minnesota Woods, to develop online content for MN Woodland Owners.

Final Report Summary:

We created and made available an online, searchable database and visualization tool of historical data (<https://mnnpn.usanpn.org/datasets>). This dataset has been downloaded 17 times to date. New data collected by citizen observers is publicly available through *Nature's Notebook*, a program of the USA-NPN (<https://www.usanpn.org/results/data>). Training videos and workshop materials are freely available via the Minnesota Phenology Network website. As described in our activity report above, we conducted >25 presentations and workshops to more than 800 people over the course of the project. We manage a Facebook page (Minnesota Phenology Network) on which we share results and create online community.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	\$ Amount	Explanation
Personnel:	\$165,138	1 project coordinator at 50% FTE for 2 years and 25% for 1 year; 1 graduate student at 25% FTE for 1 year; extension educator at 10% FTE for 2 years and 16% FTE for 1 year and undergraduate student at 34% for 1 year and 20% for 1 year
Printing:	\$4,600	Printing materials for natural resource manager and training workshops
Travel Expenses in MN:	\$5,262	Mileage, lodging and meals for consultations with phenology dataset owners and for workshops
TOTAL ENRTF BUDGET:	\$175,000	

Explanation of Use of Classified Staff: N/A

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

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 3

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
	\$	\$	
State			
University of Minnesota, Rebecca Montgomery and Roger Moon, 1% FTE (in-kind)	\$7,500	\$7,500	Supports faculty member effort on project by project manager and project partner
University of Minnesota	\$90,909	\$90,909	Unrecovered indirect costs at 52% of direct cost base of \$175,000
TOTAL OTHER FUNDS:	\$98,409	\$98,409	

VII. PROJECT STRATEGY:

A. Project Partners:

Project partners not receiving funds:

- Roger Moon (Dept. of Entomology, UMN, in-kind) will lead modeling of the relationship between climate and phenology.
- Long-term phenology observers who will provide historical datasets include:
 - John Latimer (KAXE Phenology show, Grand Rapids)
 - Jim Gilbert (retired professor, St. Peter)
 - David Palmquist (retired naturalist, Whitewater State Park, Winona)
 - Larry Weber (retired teacher, Carlton)
 - John Weber (Nevis).
- Belwin Outdoor Science, Wolf Ridge Environmental Learning Center, Will Steger Foundation will contribute to training workshops
- USA-National Phenology Network has developed and will manage the online data entry system.

B. Project Impact and Long-term Strategy:

Understanding the causes and consequences of alteration of phenology is critical for predicting future pathways of ecological communities. As a result of the work proposed here, we will identify trends in the phenology of plants and animals of Minnesota. *This new knowledge is significant because it will facilitate prediction of possible alterations in species interactions, forest community composition and forest productivity under climate change.* Forest composition and productivity critically impact the timber industry, natural resource based recreation and conservation of flora and fauna. Better understanding of the potential for alteration of economic (fiber production), recreational (parks and trails) and ecological (carbon sequestration, water quality provision) functions of forest resources under climate change will reduce uncertainties that currently hinder decision-making.

The database, training materials and web dissemination developed with ENRTF funds will be supported after 2017 by the Department of Forest Resources and the USA-NPN. The network of people and associated infrastructure represent an ongoing initiative to collect long-term phenology data across the state and make it available to resource managers, scientists, businesses and individuals. The approach can be adopted and

adapted by other organizations in the future. For example, resource management in State Parks has expressed strong interest in phenology monitoring. In addition, materials could be used for future projects such as interpretive trails at parks, nature centers, etc. that focus on phenology.

C. Spending History: N/A

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): See attached.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: N/A

XII. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 1, 2015; July 1, 2015; January 1, 2016; July 1, 2016; January 1, 2017. A final report and associated products will be submitted between June 30 and August 15, 2017.

Environment and Natural Resources Trust Fund

M.L. 2014 Project Budget

Project Title: Assessing species vulnerability to climate change using phenology

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 05e

Project Manager: Rebecca Montgomery

Organization: University of Minnesota

M.L. 2014 ENRTF Appropriation: \$ 175,000

Project Length and Completion Date: 3 Years, June 30, 2017

Date of Report: September 22, 2017

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent
BUDGET ITEM		
Personnel (Wages and Benefits)	\$78,882	\$78,882
Chris Buyarski, Project coordinator: 67% salary 33% benefits; 50% FTE for 2 years; 25% FTE for 1 year		
Stephan Carlson, UMN Extension faculty: 75% salary 25% benefits; 10% FTE for 2 years; 16% FTE for 1 year		
Claudia Nanninga, Graduate research assistant: 55% salary 44% benefits; 25% FTE for 1 year		
3 Undergraduate students: 93% salary, 7% benefits; 115% FTE for 1 year; 20% FTE for 1 year		
Printing		
Printing materials for natural resource manager workshops that emerge from Activity 1 and printing training manuals for Activity 2	\$1,350	\$1,350
Travel expenses in Minnesota		
Mileage, lodging and meals to consult with phenology record keepers, conduct natural resource manager training workshops and conduct training workshops	\$1,674	\$1,674
COLUMN TOTAL	\$81,906	\$81,906

Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	TOTAL BUDGET	TOTAL BALANCE
\$0	\$86,256	\$86,256	\$0	\$165,138	\$0
\$0	\$3,250	\$3,250	\$0	\$4,600	\$0
\$0	\$3,588	\$3,588	\$0	\$5,262	\$0
\$0	\$93,094	\$93,094	\$0	\$175,000	\$0