

M.L. 2017 Project Abstract

For the Period Ending June 30, 2021

PROJECT TITLE: Evaluating the Use of Bison to Restore and Preserve Savanna Habitat

PROJECT MANAGER: Forest Isbell

AFFILIATION: Cedar Creek Ecosystem Science Reserve, University of Minnesota

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2017, Chp. 96, Sec. 2, Subd. 08c as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

APPROPRIATION AMOUNT: \$388,000

AMOUNT SPENT: \$387,734

AMOUNT REMAINING: \$266

Sound bite of Project Outcomes and Results

Oak savanna is Minnesota's most threatened ecosystem, but effective approaches for protecting and restoring savannas remain elusive. Our project reintroduced bison to one of Minnesota's largest remaining oak savannas. We found that bison grazing helped increase oak regeneration and stimulated plant productivity, providing a promising new strategy for savanna conservation.

Overall Project Outcome and Results

Oak savanna is Minnesota's most threatened ecosystem, but effective approaches for protecting and restoring savannas remain elusive and prescribed fire, alone, is not maintaining oak savannas. Fire helps old oaks with thick bark that can survive its intense heat, in part by preventing other trees from growing and shading the oaks. However, fire also kills young oak seedlings, which prevents oak trees from regenerating. Thus, fire is a necessary, but insufficient strategy for maintaining oak savannas. We tested whether bison are essential for savanna preservation and restoration. Bison preferentially graze the most abundant native prairie grasses, which compete with young oaks and supply fuel for fires that kills them. Our project achieved the following outcomes: (1) discover better restoration and preservation practices for savanna remnants; (2) determine how these practices impact the full range of savanna biodiversity; and (3) educate Minnesotans about the ecological heritage of their state, including the roles that bison, fire and biodiversity play in the functioning of savannas and other Minnesota ecosystems. Specifically, we restored seasonal bison grazing to more than 200 acres of oak savanna, experimentally tested savanna restoration using bison grazing by establishing experimental plots and planting 660 oak seedlings, and disseminated results to more than 19,000 members of the public, in part by establishing a bison viewing gazebo. For many years to come, bison will continue to graze in these oak savannas, their impacts will continue to be assessed in experimental plots, and the public will continue to benefit from site access and programming. Our project has already attracted additional funding from the National Science Foundation's Long-Term Ecological Research Program, which will allow it to continue long after the initial support from the ENRTF. Our data are being disseminated through Cedar Creek's website and the National Science Foundation's Environmental Data Initiative.

Project Results Use and Dissemination

We have provided engagement opportunities for more than 19,000 visitors, including 2,172 K-12 students who attended field trips or online programs specifically about this research. The new bison gazebo has provided opportunities for a corps of 25 "bison naturalist" volunteers, spurred the creation of new educational resources including a savanna-themed feltboard and brochures, hosted open house events and tours, led to the design and construction of two new interpretive signs, and expanded the range of self-guided options for our community.

Additionally, one manuscript has now been submitted, another has been drafted, and the data have been made available to others.



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

Date of Submission: August 13, 2021

Final Report

Date of Work Plan Approval: 06/07/2017

Project Completion Date: June 30, 2021

PROJECT TITLE: Evaluating the Use of Bison to Restore and Preserve Savanna Habitat

Project Manager: Forest Isbell

Organization: Cedar Creek Ecosystem Science Reserve, University of Minnesota

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Location: Anoka and Isanti Counties, MN

Total ENRTF Project Budget:

ENRTF Appropriation: \$388,000

Amount Spent: \$387,734

Balance: \$266

Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 08c as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

Appropriation Language:

\$388,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Cedar Creek Ecosystem Science Reserve, to research combined bison grazing and fire management strategies to restore Minnesota's oak savanna ecosystems. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

M.L. 2020 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2021]

I. PROJECT TITLE: Restoring and Preserving Savanna Using Bison

II. PROJECT STATEMENT:

Oak savanna is Minnesota's most threatened ecosystem, and fire, alone, is not restoring and preserving it. At the time of settlement, a broad swath of savanna stretched from the south to north across the middle of Minnesota, but by the early 1900's most had become cropland and pasture. And now, after a century without fire and bison, less than 0.1% remains as savanna, and most remnants have lost their prairie grasses and wildflowers as they became dominated by trees that invaded when fire stopped.

Efforts to restore savanna have been insufficient. Our savanna restoration research started in 1965 in what had once been native savanna at Cedar Creek Ecosystem Science Reserve (henceforth "Cedar Creek"). It has shown that burning about 2 of every 3 years eliminates shrubs and non-savanna tree species and restores prairie grassland species. However, our 50 years of research is also showing that these frequent fires are preventing oaks from regenerating. Although our efforts to date have "restored" the second largest stand of oak savanna in Minnesota, it is now clear that **fire, by itself, is leading to the slow demise of this savanna because oaks are not replacing themselves before they die.** It remains unclear how oak savanna can be both restored and preserved.

We propose that bison are essential for savanna restoration and preservation because bison preferentially graze the most abundant native prairie grasses. When not grazed, these grasses can outcompete oak seedlings for soil nutrients and, when these ungrazed grasses burn, their high abundance causes intense fires that kill oak seedlings. **Fire is also likely essential** since frequent fires eliminate shrubs and most trees except oaks, thus allowing prairie species and oaks to persist.

Our **GOALS are to experimentally test whether and how bison grazing and fire can jointly restore and preserve oak savanna.** Because neither cattle nor deer nor elk preferentially eat the most abundant native grasses, we believe that bison grazing, in particular, may be of central importance to maintaining oaks in savanna ecosystems. This research on bison is essential since the role and usefulness of bison in savanna restoration and maintenance remain completely unknown.

The **OUTCOMES** we plan to achieve are to:

- (1) Discover better restoration and preservation practices for savanna remnants;
- (2) Determine how these practices impact the full range of savanna biodiversity; and
- (3) Educate Minnesotans about the ecological heritage of their state, including the roles that bison, fire and biodiversity play in the functioning of savannas and other Minnesota ecosystems.

Background:

Before the 1800's, the North American Great Plains were home to approximately 30 to 60 million bison. By the late 1800's, bison populations had been almost completely exterminated by human hunting and conversion of their habitat to croplands and rangelands for livestock, leaving only a few thousand individuals remaining. Populations have since recovered to more than one hundred thousand individuals, mostly due to ranching and conservation efforts.

Bison are now known to be a keystone species for restoring and preserving grasslands, but their potential roles in savanna restoration and preservation remain unknown. Many decades ago, it was realized that restoration of grassland biodiversity and ecosystem functioning required not only sowing of the plant community, but also reinstating natural disturbance processes, such as fire. Prescribed burning is now commonly used as a restoration practice in grasslands, savannas, and other ecosystems that historically experienced this disturbance. More recently, it has become appreciated that grassland restoration success can also be enhanced by restoring major herbivores, such as bison. Bison are now commonly used by federal and state agencies, including the US Fish and Wildlife Service (e.g., Neal Smith National Wildlife Refuge) and the Minnesota Department of Natural Resources (e.g., Blue Mounds State Park), and by private conservation organizations, such The Nature Conservancy (e.g., Broken Kettle Grasslands), to restore and preserve grasslands. Prescribed fire is commonly used in both grassland and savanna restoration projects, but bison grazing has not yet been explored as a potential management tool in savannas.

Bison preferentially graze the dominant warm season grasses that would otherwise outcompete wildflowers, thereby promoting plant coexistence and enhancing plant diversity in grasslands. By promoting grassland plant diversity, bison grazing also helps maintain ecosystem processes and the diversity of many animal species, both of which directly depend on plant diversity. We expect bison grazing will similarly promote the diversity of herbaceous (non-woody) plants in savannas, but the impacts of bison grazing on the oak trees, which dominate savannas, remains unknown.

We hypothesize that bison grazing will promote the growth and survivorship of oak seedlings in burned savannas by reducing grass fuel for fires and by knocking back dominant grass competitors; however, our proposed experiment will also test whether bison might instead disfavor oak regeneration by browsing oak seedlings. Given that bison preferentially graze warm season grasses, which are the primary fuel for fires, and which are known to outcompete oak seedlings at Cedar Creek, we expect that bison grazing will promote oak regeneration by reducing the intensity of fires and the ability of grasses to outcompete oak seedlings. Alternatively, if bison substantially browse oak seedlings, then they might instead reduce oak regeneration. If so, then bison grazing would be recommended as a strategy for restoring and preserving grasslands, but not savannas.

Because Cedar Creek is so data-rich, it provides an ideal location to study the potential role of bison grazing in maintaining savanna biodiversity and ecosystem functioning. We have collected 20-30 years of data from dozens of long-term studies that provide a detailed description of plant community structure and ecosystem function in the absence of bison. These data come from literally thousands of experimental and observational plots distributed across our 21 km² landscape. The new measurements we will collect in this project will further advance understanding of the patterns and processes driving the structure and functioning of savannas. Our results will be informed by past research, and will inform future research, at Cedar Creek.

Hypotheses:

We will investigate the following questions:

1. Does bison grazing promote oak regeneration by reducing fire intensity?
2. Does bison grazing increase promote oak regeneration, herbaceous plant diversity, and plant species that are poor competitors for soil nutrients by decreasing the ability of grasses to outcompete oak seedlings and wildflowers?

We will test the following hypotheses:

The **fire-grazing interaction hypothesis** predicts that bison grazing will promote the growth and survivorship of oak seedlings by reducing fire intensity. There would be evidence for this hypothesis if we find an interactive effect of our fire and grazing treatments on oak seedling growth and survivorship, with oak regeneration disfavored by fire, except in the presence of grazing, and if grazing reduces fire temperature in burned plots.

The **resource-apparent competition tradeoff hypothesis** predicts that plants coexist by a tradeoff between relative competitive ability for exploiting soil nutrients (resource competition) and ability to resist consumption by natural enemies, such as herbivores (apparent competition). In other words, if grasses, which are known to be superior competitors for soil nutrients at Cedar Creek, are less able to resist herbivory by bison than are oak seedlings or wildflowers, then bison grazing could promote oak regeneration and plant coexistence and diversity. There would be evidence for this hypothesis if bison increases plant diversity, decreases dominance of warm season grasses, increases oak seedling growth and survivorship, and increases dominance of wildflowers in both burned and unburned treatments.

III. OVERALL PROJECT STATUS UPDATES:

Amendment Request (10/19/2017):

We request a reallocation of our budget to reduce the cost of fence installation and to meet higher salary requirements for postdoctoral scholars resulting from the Fair Labor Standards Act. Specifically, we request to save \$10,000 on fence construction (Activity 1) by consolidating the following budget items into a fencing contract: \$28,000 from temporary and casual field assistants (Activity 1), \$58,000 from fence materials (Activity 1), \$20,000 from fence materials (Activity 2), and \$5,000 (equipment rental for adding fence posts for Activities 1 and 2). This contract (total = \$111,000) makes fence construction less expensive because the contractor is able to use specialized equipment to efficiently install the fence and is able to purchase materials at a low bulk price. This contract would include all materials and installation of the perimeter fence (Activity 1) and the materials for experimental fences that can be purchased and supplied by a contractor at the bulk discounted rate (Activity 2). This allows us to reduce by \$10,000 the budget for temporary casual employees to construct the perimeter fence (Activity 1) and to increase by \$10,000 the budget for the postdoctoral scholar salary (Activity 2). This reallocation is necessary because the Fair Labors Standards Act recently caused the University of Minnesota and other universities nationwide to increase the minimum salary for postdoctoral researchers. Without this reallocation of our budget, we would be unable to offer a full two-year appointment for the postdoc position, which would greatly limit both the number and the quality of applicants for this position. Furthermore, in our recent experience, the most qualified postdoctoral scholars are now accepting positions where they are able to negotiate salaries above the new, higher minimum level. Thus, in order to maximize the impact of the project by attracting a highly qualified postdoctoral scholar, it is now necessary for us to increase our budget for this category from \$109,000 to \$119,000.

Amendment Approved by LCCMR 10/23/2017

Project Status as of January 1, 2018:

The location of the bison enclosure was finalized, after consultation with other researchers and staff at Cedar Creek. A proposal for conducting this work at Cedar Creek was submitted, reviewed, and approved. The three-mile long perimeter fence for the 210-acre bison enclosure was completed (Activity 1). Watering facilities will be established during spring 2018.

The locations of the experimental enclosure fences that will be placed within the bison enclosure have also been determined (Activity 2). Most of the materials for these experimental fences were purchased. Two experimental fences have been constructed and 12 more will be established during spring 2018. Pre-treatment sampling of vegetation and soil will be coordinated with a remote sensing effort during spring 2018. A successful search for the postdoctoral researcher resulted in more than a dozen highly qualified applicants, four of whom will soon be interviewed.

Public seminars on this project were given at an Oak Savanna Day event and at Cedar Creek's 75th anniversary celebration. The viewing platform for visitors was purchased after receiving all required university approvals, which ensure that the platform will be structurally safe and sound (Activity 3). The viewing platform construction will be completed during spring 2018. An additional grant was obtained that will support collaboration with Native American communities when designing the signage that will be displayed on this viewing platform.

Amendment Request (01/01/2018):

We request that the Project Manager be changed from David Tilman to Forest Isbell. I (David Tilman) am fully committed to this project and will continue to dedicate my efforts to its success. However, because of Dr. Forest Isbell's central role in implementing and leading the project, it is more appropriate for Dr. Isbell to be the Project Manager.

Project Status as of July 1, 2018:

On June 13th, for the first time in nearly two centuries, 32 bison were reintroduced to more than 200 acres of the oak savannas at Cedar Creek (Activity 1). The release was a success by all accounts. Members of the media, the public, and the scientific community attended the bison release, which included a bison homecoming celebration, as further described below (Activity 3). Prior to bison reintroduction, watering facilities, two double-gates, and all 14 experimental enclosure fences were installed (Activity 2). Furthermore, the postdoctoral researcher, Chad Zirbel, was hired and began his position. Dr. Zirbel led the planting and measurement of a total of 660 oak seedlings inside and outside the enclosure. Dr. Zirbel also collected pre-treatment soil cores and is conducting daily checks of the bison herd and measuring plant biomass consumption throughout the summer.

The bison viewing gazebo was also successfully constructed and featured as the destination for the Bison Homecoming Celebration (Activity 3). Potter developed programming and trained 15 volunteers to provide natural history interpretation at the bison viewing gazebo each weekend throughout the summer. Isbell gave presentations and fielded questions about the bison reintroduction from members of the local community at the City of East Bethel's Parks Commission meeting on May 9th and at Cedar Creek on May 19th. Members of the media attended the bison release on June 19th, which led to a TV story on KSTP, and newspaper stories in the Star Tribune and other newspapers. Tilman and Isbell gave presentations at the Cedar Creek Bison Homecoming Celebration on June 13th, which was attended by 30 international scientists and 68 members of the public.

Project Status as of January 1, 2019:

Throughout the summer season, 32 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek. Dr. Zirbel and undergraduate interns conducted daily checks of the bison from their release on June 13th to their roundup on September 14th, ensuring that the bison remained well cared for. The roundup, led by Northstar Bison staff and assisted by Cedar Creek staff, occurred on foot to minimize undesirable impacts of vehicles on Cedar Creek's sensitive ecosystems. The reintroduction of bison to Cedar Creek's oak savannas was, by all measures, a success.

Plants and soils were successfully sampled by Dr. Zirbel and undergraduate interns. Data collected included plant biomass consumption by the bison, soil samples for soil total carbon and nitrogen, relative abundances of each plant species, plant light interception, plant biomass production, and the size and survivorship of planted oak seedlings. Data and metadata are also being archived in Cedar Creek's information database.

Throughout the summer season, the bison viewing gazebo hosted weekly public events with natural history interpretation provided by 15 volunteer naturalists who were trained by Potter. The project has been featured by several newspapers and TV stations. In July, Zirbel provided a tour of the bison enclosure to staff at the Sherburne National Wildlife Refuge and in August to staff from the Belwin Conservancy. In August, Isbell co-instructed a workshop for graduate students in a Global Change and Biodiversity program at the University of Zurich in Switzerland that included discussion of the costs, benefits, and ethical arguments for and against the reintroduction of bison to Cedar Creek's oak savannas. In September, Isbell and Potter provided a tour of the bison enclosure for staff from Conservation Minnesota. Potter additionally provided tours for special interest groups, including the Anoka County librarians and local senior citizens. In October, the project was discussed in a plenary seminar given by Isbell for the Minnesota Phenology Network annual meeting.

Project Status as of July 1, 2019:

During the 2019 summer season, 17 two-year-old bull bison are currently grazing in more than 200 acres of oak savanna at Cedar Creek (Activity 1). Plants and soils are once again being sampled in the 2019 growing season

(Activity 2). In the spring of 2019, Dr. Zirbel measured fire temperature and severity during prescribed burning within the savannas at Cedar Creek. After the fire, Dr. Zirbel measured survival and re-sprouting rates on the 660 oak saplings planted during the prior year. During the spring, Dr. Zirbel also installed root in-growth cores to study belowground root biomass production in areas grazed and ungrazed by bison. During July, Dr. Zirbel started measuring soil nitrogen mineralization rates. These measurements will be completed in August. In September, Dr. Zirbel will lead the collection of plant, soil, and oak seedling growth data.

The results are increasingly being disseminated to K-12 students and other visitors (Activity 3). We started the summer season with the bison release event, which was attended by Cedar Creek's members, staff and researchers. Drs. Isbell and Zirbel gave presentations on the project at this event. Since then, the bison viewing gazebo has been once again hosting weekly public events with interpretation provided by volunteers. We also added a weekday evening option once a month at the request of community members. The bison have been viewable about 70% of the open hours so far, more than might be expected given their large enclosure. New materials, including a box of bison items purchased from the InterTribal Buffalo council, poetry about the bison project written by our Artist in Residence, a spotting scope and binoculars, and a photobook of Cedar Creek's bison project, have been thoroughly enjoyed by visitors and naturalists alike. The project has been featured this year on North Metro TV, and in the Star Tribune, East Bethel Bulletin, and ABC Papers. It was also highlighted in a Lunch with a Scientist program presented by Drs. Zirbel and Potter, and has been the subject of a variety of tours and programs for students and community members. Dr. Isbell discussed the project in seminars at NASA's Jet Propulsion Lab in February, the Conservation Sciences seminar series at the University of Minnesota in February, and at the Minnesota Zoo in March. Dr. Isbell also gave tours to members of the Dakota County Parks, who are considering reintroducing bison, and the US National Park Service, who have designated Cedar Creek as a National Natural Landmark. In May, Dr. Isbell also incorporated the project into his field ecology course by developing a lecture on bison. Dr. Zirbel will present results at the Ecological Society of America's annual meeting in Louisville, Kentucky in August 2019. Dr. Zirbel is also currently writing a manuscript for submission to a scientific journal.

Project Status as of January 1, 2020:

During the 2019 summer season, 17 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek (Activity 1). This fall, a new catch pen was constructed to facilitate the annual roundup. Everything is now in place for us to continue hosting bison each summer long after the completion of this project.

Plants and soils were once again successfully sampled (Activity 2), with sampling efforts led by Dr. Zirbel. This included measurement of the relative abundances of plant species, peak plant biomass, survivorship and growth of oak seedlings, soil nitrogen mineralization, and light availability. Soil and plant samples have been archived and soil samples have now been prepared and sent to a lab for analysis. Data are being analyzed and are showing interesting results, largely consistent with our initial hypotheses. During this second growing season, oak seedling mortality was less than 25%, suggesting that a majority of the trees were able to survive the initial planting stress, the spring fires, and a second season of grazing and trampling by bison. This year, in grass-dominated plots, we found that bison grazing reduced grass biomass by nearly 47%, which likely reduces competition between grasses and young oak trees while also reducing the fuel available for spring fires. Newly analyzed results from spring 2019 show that, in grass-dominated plots, bison grazing reduced average fire temperature by 150°C and created more patchy burns, leaving some parts of the savanna unburned. We also found that oak saplings in grazed plots were about 20% more likely to survive than those in ungrazed plots. Data and metadata are being archived in Cedar Creek's information database. During spring 2020, fire temperatures will again be measured to assess whether bison reduce the intensity of fire by reducing the grass fuel for fires. After the spring fires we will again assess oak seedling survivorship.

We continue to disseminate our results widely (Activity 3), with many efforts led by Dr. Potter. Throughout the summer season and stretching into mid-October, the bison viewing gazebo hosted weekly public events with

natural history interpretation provided by trained volunteer naturalists. An average of 50 community members attended each weekly event. The project has been featured in a Big Ten Network commercial, in regional print media (East Bethel Bulletin, St. Francis Courier), and other media outlets. Filming was also done for North MetroTV which aired in July and the *Prairie Sportsman* TV series; that episode will air in 2020. Dr. Zirbel provided tours of the bison enclosure for environment staff members from a local foundation and presented results of the project at the Ecological Society of America's annual meeting in Louisville, Kentucky. Dr. Zirbel also gave a seminar on the project at the Anoka County library and is speaking at the Minnesota Bison association conference in April. Dr. Zirbel is also currently writing a manuscript for submission to a scientific journal. Dr. Isbell provided tours or talks on site for a Regent of the University of Minnesota, environment staff from a local foundation, LCCMR staff and commissioners, UMN graduate students in the mathematics program, and members of the public who attended a lunch with a scientist seminar. Dr. Isbell also discussed the project in seminars on the UMN campus in St. Paul and at a University of Zurich conference in Switzerland. Dr. Potter led field trips for several local school groups visiting on field trips, summer campers studying field biology, tours for community members and special interest organizations including the Wetlands Professional Association, Minnesota Master Naturalist volunteers, and staff and volunteers from Warner Nature Center, and discussed the project in presentations at the Anoka County Library system branch libraries and onsite at Cedar Creek for events including the Long-Term Ecological Research site annual meeting and our monthly Lunch with a Scientist series. Potter installed an art show at the University of Minnesota's Coffman Art Gallery featuring images of the savanna and bison research which was up for three months and was attended by ~500 visitors. A total of 752 K-12 students and their teachers, 483 university students and faculty, and 7967 members of the general public have now engaged with this project through K-12 field trips, the weekly public events, seminars, field days, and other programs. The majority of these participants had a focused, multi-hour experience connecting with the project. We additionally discussed the project in general terms with the additional ~6000 K-12 students and educators that participated in Cedar Creek education programs with other themes in 2019.

Project extended to June 30, 2021 by LCCMR 6/18/20 as a result of M.L. 2020, First Special Session, Chp. 4, Sec. 2, legislative extension criteria being met.

Project Status as of July 1, 2020:

During the 2020 summer season, 17 two-year-old bull bison are once again currently grazing in more than 200 acres of oak savanna at Cedar Creek (Activity 1). We continue to regularly monitor bison health, as well as the availability of forage and water.

Plants and soils are once again being sampled in the 2020 season (Activity 2). Specifically, we have measured bison consumption of plant biomass and oak sapling survival and re-sprouting rates. We also collected soil samples and completed lab analyses of previously collected soil samples. Due to the pandemic, we were unable to conduct the prescribed burns of the savannas this spring. To estimate bison consumption of plant biomass, which is also necessary for estimating plant productivity in the presence of grazing, we are using a moveable enclosure approach. This involves constructing and periodically (i.e., monthly) relocating small moveable enclosures, while harvesting plant aboveground biomass inside and outside these fences each month. Later this summer, we will collect additional data in each experimental plot (i.e., inside and outside the permanent enclosures). These data will include the peak aboveground biomass and percentage cover for each plant species, root productivity, and light interception, and oak seedling survival and growth.

Due to the pandemic, we have been unable to host in-person programs at Cedar Creek during spring and summer 2020 (Activity 3). We have, however, created two new permanent outdoor signs that will communicate results from this project to future visitors. These signs communicate the roles of bison and fire in oak savanna ecosystems, highlighting results from our studies at Cedar Creek. Additional education and community engagement work has continued online. Dr. Potter and the education staff have created a series of educational videos about prairie and savanna ecosystems, including one focused on bison, for use in fall 2020 distance-

learning programs. Dr. Zirbel and Dr. Potter have both lectured about the project in webinars to the public and to private groups. Furthermore, Dr. Zirbel is now preparing two manuscripts that report effects of bison grazing on (1) plant productivity and (2) oak survival and growth. He will also present results from this work at the Ecological Society of America's (virtual) annual meeting in August.

Project Status as of January 1, 2021:

During the 2020 summer season, 17 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek (Activity 1). Everything is in place for us to continue hosting bison each summer long after the completion of this project.

Plants and soils were once again successfully sampled (Activity 2), with sampling efforts led by Dr. Zirbel. This included measurement of the relative abundances of plant species, peak plant biomass, survivorship and growth of oak seedlings, bison consumption of plants, root productivity, and light availability. Soil and plant samples have been archived. Data are being analyzed and are showing interesting results, largely consistent with our initial hypotheses. During this second growing season, oak seedling mortality was less than 5%, suggesting that a majority of the trees were able to survive the initial planting stress, the spring fires, and a third season of grazing and trampling by bison. This year, in grass-dominated plots, we found that bison grazing again reduced grass biomass, which likely reduces competition between grasses and young oak trees while also reducing the fuel available for spring fires. We also found that oak saplings in grazed plots continued to be more likely to survive, and are now growing more, than those in ungrazed plots. Data and metadata are being archived in Cedar Creek's information database. During spring 2021, fire temperatures will again be measured to assess whether bison reduce the intensity of fire by reducing the grass fuel for fires. After the spring fires we will again assess oak seedling survivorship.

We continue to disseminate our results widely (Activity 3), with many efforts led by Dr. Potter. The project was featured through photographs and artifacts including a bison skull in a traveling display at four different local library branches, where it was viewed by approximately 3000 community members over the course of four months. One of these libraries additionally showcased bison in a virtual storytime presentation viewed by more than 300 families. Dr. Zirbel presented results of the project at the Ecological Society of America's annual meeting. Dr. Zirbel also gave a seminar on the project for Cedar Creek's virtual Lunch with a Scientist series, which was attended by 91 community members. Dr. Zirbel has written a manuscript, which will soon be submitted, that reports how bison grazing affects plant productivity above and below-ground. Dr. Zirbel is also preparing a second manuscript, which focuses on the effects of bison on oak seedling survivorship and growth. Drs. Tilman and Isbell provided tours on site for the University of Minnesota's Vice President for Research and Cedar Creek's Advisory Committee. Dr. Isbell also discussed the project in seminars for the National Science Foundation's Socio-Environmental Synthesis Center and at the Science Council meeting for the National Science Foundation's Long-Term Ecological Research Program. The pandemic dramatically curtailed summer and fall visitation and programming, but Dr. Potter was able to lead field trips for 40 students, tours for 6 individuals, and discussed the project in presentations at for native plant enthusiasts, Master Gardeners and Master Naturalists, a quilting collective, and several afterschool wildlife clubs. Naturalists supervised by Dr. Potter also created three educational videos for K-12 classrooms that highlighted the bison and their role in the savanna ecosystem. Thousands of photos of bison collected by remotely triggered trail cameras set up at Dr. Zirbel's grazing exclosures have been classed by ~4000 citizen scientist volunteers through the Eyes on the Wild Zooniverse project, and have been exposed to research results through associated blog posts and dialogue with Dr. Potter on the project comment forum.

Over the lifetime of the grant thus far, a total of 1273 K-12 students and their teachers have engaged with this project through focused field trips, virtual programming, and educational videos/resources, and an additional ~8000 students and educators have been exposed to the project through participation in Cedar Creek education programs with other themes. A total of 523 university students and faculty, and ~14,000 members of the

general public have now engaged with this project through public hours at the viewing gazebo, seminars, field days, community displays, and other programs. Many of these participants have had a focused, multi-hour experience connecting with the project in person or via their computers.

Amendment Request (04/15/2021):

We are requesting \$962 be shifted from the soil lab analyses to the experimental supplies budget.

- Soil analyses budget for Activity 2 would be reduced by \$962 to a revised budget of \$7,038.
- Experimental supplies budget for Activity 2 would be increased by \$962 to a revised budget of \$4,562.

These changes are requested because the lab analyses cost somewhat less and the supplies to establish the experiment cost somewhat more than anticipated. The scope of work remains unchanged.

Amendment Approved by LCCMR 5/7/2021.

Overall Project Outcomes and Results:

Oak savanna is Minnesota's most threatened ecosystem, but effective approaches for protecting and restoring savannas remain elusive and prescribed fire, alone, is not maintaining oak savannas. Fire helps old oaks with thick bark that can survive its intense heat, in part by preventing other trees from growing and shading the oaks. However, fire also kills young oak seedlings, which prevents oak trees from regenerating. Thus, fire is a necessary, but insufficient strategy for maintaining oak savannas. We tested whether bison are essential for savanna preservation and restoration. Bison preferentially graze the most abundant native prairie grasses, which compete with young oaks and supply fuel for fires that kills them. Our project achieved the following outcomes: (1) discover better restoration and preservation practices for savanna remnants; (2) determine how these practices impact the full range of savanna biodiversity; and (3) educate Minnesotans about the ecological heritage of their state, including the roles that bison, fire and biodiversity play in the functioning of savannas and other Minnesota ecosystems. Specifically, we restored seasonal bison grazing to more than 200 acres of oak savanna, experimentally tested savanna restoration using bison grazing by establishing experimental plots and planting 660 oak seedlings, and disseminated results to more than 19,000 members of the public, in part by establishing a bison viewing gazebo. For many years to come, bison will continue to graze in these oak savannas, their impacts will continue to be assessed in experimental plots, and the public will continue to benefit from site access and programming. Our project has already attracted additional funding from the National Science Foundation's Long-Term Ecological Research Program, which will allow it to continue long after the initial support from the ENRTF. Our data are being disseminated through Cedar Creek's website and the National Science Foundation's Environmental Data Initiative.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: *Restore bison grazing to 200 acres of oak savanna*

Description:

We will restore bison grazing to a 200-acre-site on the southwest edge of Cedar Creek that is a mosaic of restored oak savanna (that lacks oak regeneration) and remnant oak savanna (that is now low-diversity forest). In 2017, we will install bison fencing around this parcel, watering facilities, and a bison corral. Then, starting in late spring of 2018 and each subsequent year, a project partner, Northstar Bison, will deliver and release bison, periodically visit throughout the growing season to provide any needed veterinary services, collect any bison that might escape, mend fences, and round-up bison each year in October. A similar seasonal bison grazing partnership between Northstar Bison and Belwin Conservancy has successfully restored prairie grassland with minimal ongoing costs for Belwin. We cannot afford to purchase, or to maintain all year for many years, a herd

of 100% genetically pure bison for this research and, fortunately, do not need to do so since Northstar’s bison preferentially graze abundant native grasses just as do genetically pure bison.

Restoration goals include promoting oak regeneration, enhancing the biodiversity of plants and animals, and maintaining ecosystem functioning and stability. The experiment in Activity 2, described below, will be used to assess whether these restoration goals are achieved. We will control the intensity and timing of bison grazing with adaptive management to achieve restoration goals.

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 89,333
Amount Spent: \$ 89,333
Balance: \$ 0

Outcome	Completion Date
1. Perimeter fences and bison corrals constructed and watering facilities established	November 2017
2. About 40 bison grazing in 200 acres of current and remnant savanna	June 2018
3. About 40 bison grazing in 200 acres of current and remnant savanna	June 2019
4. About 40 bison grazing in 200 acres of current and remnant savanna	June 2020

Activity 1 Status as of January 1, 2018:

The location of the bison enclosure was finalized, after consultation with other researchers and staff at Cedar Creek. A proposal for conducting this work at Cedar Creek was submitted, reviewed, and approved. The three-mile long perimeter fence for the 210-acre bison enclosure was completed (Activity 1). This included marking out the location of the fence, clearing brush in the path of the fence-line, selecting a fence contractor through a competitive bidding process approved by purchasing services to ensure a fair and efficient price, and overseeing construction of the fence. The collaborator supplying the bison will also supply a portable corral for the end of season roundup of bison. Watering facilities will be established during spring 2018.

Activity 1 Status as of July 1, 2018:

Watering facilities were established, including the addition of two wells, one with a solar pump and a secondary backup well that runs from a portable generator. Two double-gates were installed as the only entry and exit points for vehicles while the bison are on site, in order to reduce the risk that a gate will be left open during entry or exit from the bison enclosure. On 13 June, for the first time in nearly two centuries, 32 bison were reintroduced to more than 200 acres of the oak savannas at Cedar Creek. The release was a success by all accounts. Given that this was the first year of returning bison to these ecosystems, and to ensure that overgrazing was avoided, we introduced 32 two-year-old bull bison and we plan to have them on site for a relatively short grazing season. Members of the media, the public, and the scientific community attended the bison release, which included a bison homecoming celebration, as further described below.

Activity 1 Status as of January 1, 2019:

Throughout the summer season, 32 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek. Dr. Zirbel and undergraduate interns conducted daily checks of the bison from their release on June 13th to their roundup on September 14th, ensuring that there were no bison fatalities, no injuries that required veterinary care, and sufficient availability of both water and forage. The roundup, led by Northstar Bison staff and assisted by Cedar Creek staff, occurred on foot to minimize undesirable impacts of vehicles on Cedar Creek’s sensitive ecosystems. The reintroduction of bison to Cedar Creek’s oak savannas was, by all measures, a success.

Activity 1 Status as of July 1, 2019:

During the 2019 summer season, 17 two-year-old bull bison are currently grazing in more than 200 acres of oak savanna at Cedar Creek. Note that although there is no remaining budget for this activity, bison will continue to come to Cedar Creek in future years because the budgeted expenses for this activity were setup costs, primarily to establish the fences, gates, and water facilities needed for the bison.

Activity 1 Status as of January 1, 2020:

During the 2019 summer season, 17 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek. Although the numbers of bison grazing in the enclosure (i.e., 32 during 2018 and 17 during 2019) are less than the 40 bison we originally estimated could graze in this area, we are still accomplishing our goals of determining the roles of bison in oak savanna. Our stocking rates are determined in collaboration with the bison ranchers, who are experts in determining what is best for the bison, and by considering the impacts of the bison on our oak savannas. The bison are consuming the targeted amounts of aboveground plant biomass production, and this grazing is substantially altering the impacts of fire and the oaks (see results reported below in Activity 2). This fall, a new catch pen was constructed to facilitate the annual roundup. Everything is now in place for us to continue hosting bison each summer long after the completion of this project.

Activity 1 Status as of July 1, 2020:

During the 2020 summer season, 17 two-year-old bull bison are once again currently grazing in more than 200 acres of oak savanna at Cedar Creek. Note that although there is no remaining budget for this activity, bison will continue to come to Cedar Creek in future years because the budgeted expenses for this activity were setup costs. We continue to regularly monitor bison health, as well as the availability of forage and water.

Activity 1 Status as of January 1, 2021:

During the 2020 summer season, 17 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek. Everything is in place for us to continue hosting bison each summer long after the completion of this project.

Final Report Summary:

During the 2021 summer season, 16 two-year-old bull bison grazed in more than 200 acres of oak savanna at Cedar Creek. Prior to bison grazing, a three-mile-long perimeter fence was constructed for the bison enclosure, which is 210 acres. In total, 82 two-year-old bison grazed in the oak savanna over the four summers of the project. Each year, we monitor the health of the bison throughout the summer season. Everything is in place for us to continue hosting bison each summer long after the completion of this project.

ACTIVITY 2: *Experimental tests of savanna restoration using bison*

Description:

Within the 200-acre bison enclosure we will create a well-replicated experiment to determine how bison grazing and fire frequency impact the restoration and preservation of oak savanna ecosystems. Using 54 plots, each 7 m x 21 m in size, we will determine the impacts of all combinations of 3 fire frequencies crossed with either bison grazing or no bison grazing. Half of the plots would be fenced to exclude bison. Survivorship and growth of transplanted oak seedlings, and of prairie species, light availability, fire temperature, and soil moisture and chemistry would be measured each summer to determine the impacts of bison and fire frequency. Pre-treatment measurements of plants and soils will occur during 2017, before the bison are introduced during 2018. This experiment will have the statistical power needed to test our hypotheses and determine the roles of bison and fire in savanna restoration and preservation.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 278,267

Amount Spent: \$ 278,258

Balance: \$ 9

Outcome	Completion Date
1. <i>Experimental fences constructed</i>	November 2017
2. <i>Pre-treatment plant and soil sampling completed</i>	October 2017
3. <i>Oak seedlings transplanted both inside and outside bison grazing exclosures</i>	May 2018
4. <i>Plant and soil sampling completed</i>	August 2018
5. <i>Plant and soil sampling completed</i>	August 2019
6. <i>Plant and soil data analyzed and results submitted for publication</i>	May 2020

Activity 2 Status as of January 1, 2018:

The locations of the experimental enclosure fences that will be placed within the bison enclosure were determined (Activity 2). Most of the materials for the experimental fences were purchased. Two experimental fences were constructed and 12 more will be established during spring 2018. A new grant was obtained that will allow remote sensing of vegetation throughout the entire bison enclosure. As a result, pre-treatment sampling of vegetation and soil on the ground was postponed to be coordinated with this broader landscape-scale remote sensing effort during spring 2018. A successful search for the postdoctoral researcher resulted in more than a dozen highly qualified applicants, four of whom we will interview on January 9, 2018. This hire will be completed shortly thereafter.

Activity 2 Status as of July 1, 2018:

All 14 experimental exclosures were constructed and in place before the bison were released. The postdoctoral researcher, Chad Zirbel, was hired and began his position. Dr. Zirbel led the planting of a total of 660 oak seedlings inside and outside the exclosure, watering of oak seedlings during the first month of establishment, and replacement of tree individuals that died during the initial establishment phase. Before the bison were released, Dr. Zirbel also led the measurement of pre-treatment plant data, which included measurement of the diameter and height of all the oak seedlings, and collected pre-treatment soil cores. Dr. Zirbel is conducting daily checks of the bison herd and measuring plant biomass consumption throughout the summer and will lead the collection of plant and soil data in August and September.

Activity 2 Status as of January 1, 2019:

Plants and soils were successfully sampled. Throughout the summer, Dr. Zirbel continued measuring plant biomass consumption by the bison. At the end of the summer, Dr. Zirbel led the collection of plant and soil data in each of the experimental plots. Soil cores were collected in June for measuring baseline soil carbon and nitrogen. These soil samples have now been prepared and will soon be sent to a lab for analysis. In August, the percentage cover for each plant species and light interception were recorded in each experimental plot. In September, peak aboveground herbaceous plant biomass was clipped, sorted to species, dried, and weighed. In October, the size (heights and diameters) and survivorship of each of the 660 planted oak seedlings were measured. During the first growing season, oak seedling mortality was less than 2%, suggesting that a majority of the trees were able to survive the initial planting stress and a season of trampling by bison. Thus, the experiment is now well-positioned to study the effects of fire intensity on oak survival. Soil and plant samples have been archived. Data and metadata are also being archived in Cedar Creek's information database. During spring 2019, fire temperatures will be measured to assess whether bison reduce the intensity of fire by reducing the grass fuel for fires.

Activity 2 Status as of July 1, 2019:

Plants and soils are once again being sampled in the 2019 growing season. In the spring of 2019, Dr. Zirbel measured fire temperature and severity during prescribed burning within the savannas at Cedar Creek. After the fire, Dr. Zirbel measured survival and re-sprouting rates on the 660 oak saplings planted in the spring of 2018. On average, as predicted, fires were cooler in areas grazed by bison. Grazing by bison also increased oak tree survival in areas that could not carry fire, also as predicted. In areas where fires did burn, 99% of the oak tree stems burned, but of these burned trees, 70% re-sprouted. During the spring, Dr. Zirbel also installed root in-growth cores to study belowground root biomass production in areas grazed and ungrazed by bison. During July, Dr. Zirbel started measuring soil nitrogen mineralization rates. These measurements will be completed in August. In September, Dr. Zirbel will lead the collection of plant, soil, and oak seedling growth data.

Activity 2 Status as of January 1, 2020:

Plants and soils were once again successfully sampled, led by Dr. Zirbel. In July and August, nitrogen mineralization was measured. Soil samples have now been prepared and sent to a lab for analysis. At the end of the summer, plant data were collected in each of the experimental plots. Specifically, in August, the percentage cover for each plant species and light interception were recorded in each experimental plot. In September, peak aboveground herbaceous plant biomass was clipped, sorted to species, dried, and weighed. Soil and plant samples have been archived. In October, the size (heights and diameters) and survivorship of each of the 660 planted oak seedlings were measured. During this second growing season, oak seedling mortality was less than 25%, suggesting that a majority of the trees were able to survive the initial planting stress, the spring fires, and a second season of grazing and trampling by bison. In 2019, in grass-dominated plots, we found that bison grazing reduced grass biomass by nearly 47%, which likely reduces competition between grasses and young oak trees while also reducing the fuel available for spring fires. Newly analyzed results from spring 2019 show that, in grass-dominated plots, bison grazing reduced average fire temperature by 150°C and created more patchy burns, leaving some parts of the savanna unburned. We also found that oak saplings in grazed plots were about 20% more likely to survive than those in ungrazed plots. Data and metadata are being archived in Cedar Creek's information database. During spring 2020, fire temperatures will again be measured to assess whether bison reduce the intensity of fire by reducing the grass fuel for fires. After the spring fires we will again assess oak seedling survivorship.

Activity 2 Status as of July 1, 2020:

Plants and soils are once again being sampled in the 2020 season. In the first part of 2020, we measured bison consumption of plant biomass and oak sapling survival and re-sprouting rates. We also collected soil samples and completed lab analyses of previously collected soil samples. Due to the pandemic, we were unable to conduct the prescribed burns of the savannas this spring. To estimate bison consumption of plant biomass, which is also necessary for estimating plant productivity in the presence of grazing, we are using a moveable exclosure approach. This involves constructing and periodically (i.e., monthly) relocating small moveable exclosures, while harvesting plant aboveground biomass inside and outside these fences each month. Dr. Zirbel is now preparing two manuscripts that report effects of bison grazing on (1) plant productivity and (2) oak survival and growth. See above for some of the results that will be reported in these publications. Later this summer, we will collect additional data in each experimental plot (i.e., inside and outside the permanent exclosures). These data will include the peak aboveground biomass and percentage cover for each plant species, root productivity, and light interception, and oak seedling survival and growth.

Activity 2 Status as of January 1, 2021:

Plants and soils were once again successfully sampled, with sampling efforts led by Dr. Zirbel. This included measurement of the relative abundances of plant species, peak plant biomass, survivorship and growth of oak seedlings, bison consumption of plants, root productivity, and light availability. Soil and plant samples have been archived. Data are being analyzed and are showing interesting results, largely consistent with our initial

hypotheses. During this second growing season, oak seedling mortality was less than 5%, suggesting that a majority of the trees were able to survive the initial planting stress, the spring fires, and a third season of grazing and trampling by bison. This year, in grass-dominated plots, we found that bison grazing again reduced grass biomass, which likely reduces competition between grasses and young oak trees while also reducing the fuel available for spring fires. We also found that oak saplings in grazed plots continued to be more likely to survive, and are now growing more, than those in ungrazed plots. Data and metadata are being archived in Cedar Creek's information database. During spring 2021, fire temperatures will again be measured to assess whether bison reduce the intensity of fire by reducing the grass fuel for fires. After the spring fires we will again assess oak seedling survivorship.

Final Report Summary:

Plants and soils continue to be sampled in the 2021 season. Due to the pandemic, we were unable to conduct the prescribed burns of the savannas this spring. Dr. Zirbel has now submitted one manuscript that reports effects of bison grazing on plant productivity. He has also drafted another manuscript that reports effects of bison grazing on oak survival and growth. Later this summer, we will collect additional data in each experimental plot (i.e., inside and outside the permanent exclosures), using additional funds. These data will include the peak aboveground biomass and percentage cover for each plant species, light interception, and oak seedling survival and growth. Experimental exclosures were established, 660 oak seedlings were planted in experimental plots both inside and outside grazing exclosures, and measurements of plants and soils were made each summer. Funding has been secured to continue these measurements in future years.

ACTIVITY 3: Disseminate results to K-12 students and visitors

Description:

We propose to inform and educate Minnesotans about the ecological heritage of their state, including the roles that bison, fires and biodiversity play in the functioning of savannas and other Minnesota ecosystems, by providing educational programming for the thousands of K-12 students and other visitors who come to Cedar Creek each year and by creating an accessible viewing area (slightly-elevated wooden deck with insect screening) with educational signs and handouts that is open to the public whenever bison are on-site.

Education programs will be developed to correspond with state and national academic standards, and will incorporate both observational and inquiry-based activities. Observational programs will involve groups learning about bison adaptations, behavior and diet from trained naturalists, in conjunction with time spent in the viewing area watching the bison move through the landscape. Inquiry-based programs, also led by trained naturalists, will require students to generate hypotheses about the impact of fire and grazing on plant communities, and then either collect data (e.g. measure tree diameter, measure light penetration, estimate tree vs. grass cover) or analyze data previously collected by Cedar Creek scientists that support or reject their hypotheses. All programs will also include information and hands-on activities highlighting the role of large herbivores on the landscape, the historical range and impact of bison in Minnesota, and the importance of bison and fire to indigenous Minnesotans and to land managers working to understand savanna dynamics.

During the months that bison are on site, public outreach programs will also take place. These will involve 'open-house' style events at the viewing platform, where visitors can drop by to observe the bison and interact with trained interpreters, as well as organized tours and activities focused on bison adaptations, impact and historical importance in Minnesota. Results from ongoing research into fire, grazing and oak savannas will be disseminated at these events.

Summary Budget Information for Activity 3:

ENRTF Budget: \$ 20,400
Amount Spent: \$ 20,143
Balance: \$ 257

Outcome	Completion Date
1. <i>Viewing platform constructed and educational signs displayed</i>	November 2017
2. <i>At least 10,000 K-12 students and visitors benefit from educational programming</i>	May 2020

Activity 3 Status as of January 1, 2018:

A public Oak Savanna Day event was held on July 22, 2017 that featured a presentation on this bison project and a panel discussion and question and answer session that included representatives of the science (Forest Isbell), education and outreach programs (Caitlin Potter), and bison management (Lee Graese, founder and owner of Northstar Bison). Isbell also gave a talk on this bison project at Cedar Creek’s 75th anniversary celebration on September 9, 2017. The viewing platform for visitors was purchased after receiving all required university approvals, which ensure that the platform will be structurally safe and sound. This viewing platform will provide viewing access for education groups, public tours and visitors. It will be located on a trail with signage and handouts that share information about savanna ecology, flora and fauna, and research. The signage and physical materials for the trail are currently being developed in collaboration with local students and professors from Anoka-Ramsey Community College. Volunteer naturalists have been recruited to staff the viewing platform and to provide interpretive information on the bison and the research project during the summer. The viewing platform construction will be completed during spring 2018. An additional grant was obtained that will support collaboration with Native American communities when designing the signage that will be displayed on this viewing platform. Meetings have been held with local teachers about bison- and savanna-related field trip programming for our fall education season and curriculum is being developed to share the research and its results with the thousands of students who visit Cedar Creek annually.

Activity 3 Status as of July 1, 2018:

The bison viewing gazebo was successfully constructed before the bison arrived. Trail signs were added to direct people as they walk to the bison viewing gazebo from a safe parking zone at a park that is co-managed by Cedar Creek and the City of East Bethel. The bison viewing gazebo featured as the destination for the Bison Homecoming Celebration (see below) and has served as a base for natural history interpretation throughout the summer. Potter developed programming and trained 15 volunteers to provide natural history interpretation at the bison viewing gazebo each weekend throughout the summer. Isbell gave a presentations and fielded questions about the bison reintroduction from members of the local community at the City of East Bethel’s Parks Commission meeting on May 9th and at Cedar Creek on May 19th. Members of the media attended the bison release on June 19th, which led to a TV story on KSTP (local ABC channel: <https://kstp.com/news/research-project-brings-bison-back-central-minnesota-cedar-creek-east-bethel/4948813>), and newspaper stories in the Star Tribune (<http://www.startribune.com/can-bison-help-save-oak-savanna-scientists-look-to-anoka-county-herd-to-find-out/485745622/>), and several other UMN and local news outlets. Tilman and Isbell gave presentations, and Tilman and others led field tours of the oak savanna, at the Cedar Creek Bison Homecoming Celebration on June 13th, which was attended by 30 international scientists and biodiversity experts and 68 members of the general public.

Activity 3 Status as of January 1, 2019:

Throughout the summer season, the bison viewing gazebo hosted weekly public events with natural history interpretation provided by volunteer naturalists trained by Potter. An average of 50 community members attended each weekly event. The project has been featured in the Chippewa Herald, US News and World Report, the Star Tribune, KSTP, the Minnesota Daily, and other media outlets. In July, Zirbel provided tours of the bison enclosure to staff from Sherburne National Wildlife Refuge and in August to staff from Belwin Conservancy. Potter led tours for the Anoka County Library staff and local groups of senior citizens. In August, Isbell co-instructed a workshop for graduate students in a Global Change and Biodiversity program at the University of Zurich in Switzerland that included discussion of the costs, benefits, and ethical arguments for and against the reintroduction of bison to Cedar Creek’s oak savannas. In September, Isbell and Potter provided a tour of the

bison enclosure for staff from Conservation Minnesota. In October, the project was discussed in a plenary seminar given by Isbell for the Minnesota Phenology Network annual meeting. In December, Potter gave a presentation about the project for the Springbrook Nature Center "Discovery Dinners" series. A total of 220 K-12 students, 165 university students and faculty, and 1,119 additional visitors from the general public have now engaged with this project through K-12 field trips, the weekly public events, seminars, field days, and other programs.

Activity 3 Status as of July 1, 2019:

Results from the project are being disseminated to K-12 students and other visitors (Activity 3). We started the summer season with the bison release event, which was attended by Cedar Creek's members, staff and researchers. Drs. Isbell and Zirbel gave presentations on the project at this event. Since then, the bison viewing gazebo has been once again hosting weekly public events with interpretation provided by volunteers. After the success of our first summer, we decided to expand the hours the gazebo was staffed and add additional signage and benches (made by a local Eagle Scout) on the trail. We also added a weekday evening option once a month at the request of community members. The bison have been viewable about 70% of the open hours so far, more than might be expected given their large enclosure, and we generally serve between 30 and 60 visitors each week. New materials, including a box of bison items purchased from the InterTribal Buffalo council, poetry about the bison project written by our Artist in Residence, a spotting scope and binoculars, and a photobook of Cedar Creek's bison project, have been thoroughly enjoyed by visitors and naturalists alike. The project has been featured this year on North Metro TV, and in the Star Tribune, East Bethel Bulletin, and ABC Papers. It was also highlighted in a Lunch with a Scientist program presented by Drs. Zirbel and Potter, and has been the subject of a variety of tours and programs for students and community members. Dr. Isbell discussed the project in seminars at NASA's Jet Propulsion Lab in February, the Conservation Sciences seminar series at the University of Minnesota in February, and at the Minnesota Zoo in March. Dr. Isbell also gave tours to members of the Dakota County Parks, who are considering reintroducing bison, and the US National Park Service, who have designated Cedar Creek as a National Natural Landmark. In May, Dr. Isbell also incorporated the project into his field ecology course by developing a lecture on bison. Dr. Zirbel will present results at the Ecological Society of America's annual meeting in Louisville, Kentucky in August 2019. Dr. Zirbel is also currently writing a manuscript for submission to a scientific journal. A total of 301 K-12 students, 329 university students and faculty, and 1,809 additional visitors from the general public have now engaged with this project through K-12 field trips, the weekly public events, seminars, tours, and other programs.

Activity 3 Status as of January 1, 2020:

Throughout the summer season and stretching into mid-October, the bison viewing gazebo hosted weekly public events with natural history interpretation provided by volunteer naturalists trained by Dr. Potter. An average of 50 community members attended each weekly event. The project has been featured in a Big Ten Network commercial, in regional print media (East Bethel Bulletin, St. Francis Courier), and other media outlets. Filming was also done for North MetroTV which aired in July and the *Prairie Sportsman* TV series; that episode will air in 2020. Dr. Zirbel provided tours of the bison enclosure for environment staff members from a local foundation and presented results of the project at the Ecological Society of America's annual meeting in Louisville, Kentucky. Dr. Zirbel also gave a seminar on the project at the Anoka County library and is speaking at the Minnesota Bison association conference in April. Dr. Zirbel is also currently writing a manuscript for submission to a scientific journal. Dr. Isbell provided tours or talks on site for a Regent of the University of Minnesota, environment staff from a local foundation, LCCMR staff and commissioners, UMN graduate students in the mathematics program, and members of the public who attended a lunch with a scientist seminar. Dr. Isbell also discussed the project in seminars on the UMN campus in St. Paul and at a University of Zurich conference in Switzerland. Dr. Potter led field trips for several local school groups visiting on field trips, summer campers studying field biology, tours for community members and special interest organizations including the Wetlands Professional Association, Minnesota Master Naturalist volunteers, and staff and volunteers from

Warner Nature Center, and discussed the project in presentations at the Anoka County Library system branch libraries and onsite at Cedar Creek for events including the Long-Term Ecological Research site annual meeting and our monthly Lunch with a Scientist series. Potter installed an art show at the University of Minnesota's Coffman Art Gallery featuring images of the savanna and bison research which was up for three months and was attended by ~500 visitors. Additionally, more than 5000 individuals from across the US and overseas connected with the project through our *Eyes on the Wild* camera trap project. There are 8 remotely triggered trail cameras either inside or directly adjacent (and looking into) the bison enclosure which capture thousands of images of the herd while they are onsite. Volunteers look at the images and identify the species photographed, as well as the number of animals and their behavior. Bison are consistently one of the most popular species found and provide an excellent opportunity for participants to engage with this research project. A total of 752 K-12 students and their teachers, 483 university students and faculty, and 7967 members of the general public have now engaged with this project through K-12 field trips, the weekly public events, seminars, field days, and other programs. The majority of these participants had a focused, multi-hour experience connecting with the project. We additionally discussed the project in general terms with the additional ~6000 K-12 students and educators that participated in Cedar Creek education programs with other themes in 2019.

Activity 3 Status as of July 1, 2020:

Due to the pandemic, we have been unable to host in-person programs at Cedar Creek during spring and summer 2020. We have, however, created two new permanent outdoor signs that will communicate results from this project to future visitors. These signs communicate the roles of bison and fire in oak savanna ecosystems, highlighting results from our studies at Cedar Creek. Additional education and community engagement work has continued online, as well as in-person in the first few months of the year. Dr. Potter and the education staff have created a series of educational videos about prairie and savanna ecosystems, including one focused on bison, for use in fall 2020 distance-learning programs. Dr. Zirbel presented a well-attended (>100 participants) webinar about the project as part of our monthly Lunch with a Scientist series. Dr. Potter spoke about the project to a variety of audiences, including elementary students at several local schools, Master Naturalists participating in a training course, the University of Minnesota Public Engagement Network, volunteers from the Bell Museum, and the Big Rivers Big Woods chapter of Wild Ones. A total of 886 K-12 students and their teachers, 555 university students and faculty, and 8290 members of the general public have now deeply engaged with this project through K-12 field trips, public events, seminars, field days, and other programs. An additional ~10,000 K-12 students and their teachers were exposed to the project while attending Cedar Creek education programs with other themes in 2018 and 2019.

Activity 3 Status as of January 1, 2021:

We continue to disseminate our results widely, with many efforts led by Dr. Potter. Due to the pandemic, we have been unable to host in-person programs at Cedar Creek during much of 2020. Education and community engagement work has continued either online or in open community spaces. The project was featured through photographs and artifacts including a bison skull in a traveling display at four different local library branches, where it was viewed by approximately 3000 community members over the course of four months. One of these libraries additionally showcased bison in a virtual storytime presentation viewed by more than 300 families. Dr. Zirbel provided tours of the bison enclosure for visitors and presented results of the project at the Ecological Society of America's annual meeting. Dr. Zirbel also gave a public seminar on the project for Cedar Creek's virtual Lunch with a Scientist series, which was attended by 91 community members. Dr. Zirbel has written a manuscript, which will soon be submitted, that reports how bison grazing affects plant productivity above and below-ground. Dr. Zirbel is also preparing a second manuscript, which focuses on the effects of bison on oak seedling survivorship and growth. Drs. Tilman and Isbell provided tours on site for the University of Minnesota's Vice President for Research and Cedar Creek's Advisory Committee. Dr. Isbell also discussed the project in seminars for the National Science Foundation's Socio-Environmental Synthesis Center and at the Science Council meeting for the National Science Foundation's Long-Term Ecological Research Program. Dr. Potter led field trips

for 40 students, tours for 6 individuals, and discussed the project in presentations at for native plant enthusiasts, Master Gardeners and Master Naturalists, a quilting collective, and several afterschool wildlife clubs. Naturalists supervised by Dr. Potter also created three educational videos for K-12 classrooms that highlighted the bison and their role in the savanna ecosystem. Thousands of photos of bison collected by remotely triggered trail cameras set up at Dr. Zirbel's grazing exclosures have been classed by ~4000 citizen scientist volunteers through the Eyes on the Wild Zooniverse project, and have been exposed to research results through associated blog posts and dialogue with Dr. Potter on the project comment forum.

Over the lifetime of the grant thus far, a total of 1273 K-12 students and their classroom teachers have engaged with this project through focused field trips, virtual programming, and educational videos/resources, and an additional ~8000 students and educators have been exposed to the project through participation in Cedar Creek education programs with other themes. A total of 523 university students and faculty, and ~14,000 members of the general public have now engaged with this project through public hours at the viewing gazebo, seminars, field days, community displays, and other programs. Many of these participants have had a focused, multi-hour experience connecting with the project in person or via their computers.

Final Report Summary:

We continue to disseminate our results widely, with many efforts led by Dr. Potter. Despite the ongoing pandemic, we have been able to safely resume some public programs at Cedar Creek (including re-opening the bison gazebo to our community) while continuing with online programming including a lecture by Dr. Zirbel, a citizen science trail camera project, additional videos and classroom resources, outdoors tours, and zoom programs for schools and summer camps. Over the lifetime of this grant, we have provided programs, events and engagement opportunities for more than 19,000 community members and students. Included in that number are 2,172 K-12 students who have attended field trips or online programs specifically about this research. An additional 10,000 students and educators have been exposed to the project through participation in Cedar Creek educational programs with complementary themes. The addition of the bison gazebo to our landscape has provided new volunteer opportunities for a corps of 25 "bison naturalist" volunteers, spurred the creation of new educational resources including an oak savanna feltboard, photo books and new brochures, hosted open house events and dedicated tours, led to the design and construction of two new interpretive signs, and expanded the range of self-guided options for our local community.

V. DISSEMINATION:

Description:

We will communicate results to the scientific community by submitting approximately two peer-reviewed scientific journal articles for publication. We will communicate findings to the general public by offering education and outreach programs on site. Data will be archived and disseminated via the Cedar Creek website. We will share our publications with land managers at federal and state agencies, including the US Fish and Wildlife Service and the Minnesota Department of Natural Resources, and with private conservation organizations, including The Nature Conservancy.

Status as of January 1, 2018:

A public Oak Savanna Day event was held on July 22, 2017 that featured a presentation on this bison project and a panel discussion and question and answer session that included representatives of the science (Forest Isbell), education and outreach programs (Caitlin Potter), and bison management (Lee Graese, founder and owner of Northstar Bison). Isbell also gave a talk on this bison project at Cedar Creek's 75th anniversary celebration on September 9, 2017. The viewing platform for visitors was purchased after receiving all required university approvals, which ensure that the platform will be structurally safe and sound. This viewing platform will provide viewing access for education groups, public tours and visitors. It will be located on a trail with signage and handouts that share information about savanna ecology, flora and fauna, and research. The signage and physical

materials for the trail are currently being developed in collaboration with local students and professors from Anoka-Ramsey Community College. Volunteer naturalists have been recruited to staff the viewing platform and to provide interpretive information on the bison and the research project during the summer. The viewing platform construction will be completed during spring 2018. An additional grant was obtained that will support collaboration with Native American communities when designing the signage that will be displayed on this viewing platform. Meetings have been held with local teachers about bison- and savanna-related field trip programming for our fall education season and curriculum is being developed to share the research and its results with the thousands of students who visit Cedar Creek annually.

Status as of July 1, 2018:

See report on Activity 3 above for reporting of several public engagement events. The first results will be obtained during the next reporting period, after which we will disseminate results.

Status as of January 1, 2019:

See report on Activity 3 above for a description of several public engagement events. Data have now been collected, analyses are underway, and results will begin to be disseminated during 2019. Additional education programs for K-12 field trips are being developed for delivery in 2019.

Status as of July 1, 2019:

See report on Activity 3 above for a description of several public engagement events. Data have now been collected, analyses are underway, and results are beginning to be disseminated, as described above.

Status as of January 1, 2020:

See report on Activity 3 above for a description of several public engagement events. Data have now been collected, analyses are underway, and results are beginning to be disseminated, as described above.

Status as of July 1, 2020:

Due to the pandemic, we have been unable to host in-person programs at Cedar Creek during spring and summer 2020. We have, however, created two new permanent outdoor signs that will communicate results from this project to future visitors. These signs communicate the roles of bison and fire in oak savanna ecosystems, highlighting results from our studies at Cedar Creek. Education and community engagement work has continued online and through the development of digital resources, which has extended the reach of this project beyond the immediate Cedar Creek community. Furthermore, Dr. Zirbel is now preparing two manuscripts that report effects of bison grazing on (1) plant productivity and (2) oak survival and growth. He will also present results from this work at the Ecological Society of America's (virtual) annual meeting in August.

Status as of January 1, 2021:

See report on Activity 3 above for a description of several public engagement events. Data have now been collected, analyses are underway, and results are beginning to be disseminated, as described above.

Final Report Summary:

See report on Activity 3 above for a description of dissemination efforts. Furthermore, one manuscript has been submitted for publication and another has been drafted. Data and metadata have been formally archived and disseminated via Cedar Creek's website and the National Science Foundation's Environmental Data Initiative.

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:	\$237,000	1 postdoctoral scholar at 100% FTE for 2 years to lead field data collection and analysis efforts and publish papers (\$119,000). 3 undergraduate research assistants during year 1 and 5 undergraduate research assistants during years 2 and 3, each at 25% FTE, to assist with sampling plants and soils (\$99,000). 2 temporary employees at 17% FTE during year 1 to install experimental fences and watering facilities (\$19,000).
Equipment/Tools/Supplies:	\$32,000	Interior fencing (\$8,000). Bison education viewing area (\$16,000). Experiment supplies (\$3,600). Education supplies (\$4,400).
Contract	\$111,000	Materials and installation of perimeter fence and bulk materials for experimental fences.
Other:	\$8,000	Lab analyses for soil samples (\$8,000).
TOTAL ENRTF BUDGET:	\$388,000	

Explanation of Use of Classified Staff: NA

Explanation of Capital Expenditures Greater Than \$5,000: NA

Total Number of Full-time Equivalent (FTE) Directly Funded with this ENRTF Appropriation: 6.25

Total Number of Full-time Equivalent (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			
	\$0	\$0	
State			
Indirect costs associated with this project waived by UMN	\$207,000	\$207,000	
TOTAL OTHER FUNDS:	\$207,000	\$207,000	

VII. PROJECT STRATEGY:

A. Project Partners:

Partners receiving ENRTF funding

None

Partners NOT receiving ENRTF funding

Dr. David Tilman, Director, Cedar Creek Ecosystem Science Reserve, Regents Professor, University of Minnesota, Project Manager, oversee project

Dr. Forest Isbell, Associate Director, Cedar Creek Ecosystem Science Reserve and Adjunct Assistant Professor, University of Minnesota, Project Manager, supervise work on-site at Cedar Creek Ecosystem Science Reserve

Dr. Caitlin Barale Potter, Education and Outreach Coordinator, Cedar Creek Ecosystem Science Reserve, University of Minnesota, Collaborator, co-lead Activity 3

B. Project Impact and Long-term Strategy:

Our results will guide efforts by state and federal agencies and conservation organizations to restore oak savanna across the state. To maximize what is learned from reintroducing bison to Cedar Creek, we aim to maintain bison grazing as long as possible. The partnership with Northstar Bison makes this financially feasible since they provide and care for the bison each year at no cost to Cedar Creek, thus allowing the project to continue potentially indefinitely. Moreover, we have successfully attracted major federal research funding to Cedar Creek for more than three decades and will seek such funding to continue sampling the bison experiment at the end of the proposed 3 years of LCCMR support.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	\$ Amount
<i>National Fish and Wildlife Foundation- Project ID 99908.05.017860: Grant of cash for savanna restoration</i>	7/2005-7/2008	\$55,895
<i>Minnesota Environmental and Natural Resource Trust Fund- ML 2005, first Special Session, Chapt. 1, Art. 2, Sec. 11, Subd. 11(b): Appropriation of cash funds used for savanna restoration</i>	7/2006-6/2008	\$141,638

VIII. REPORTING REQUIREMENTS:

- **The project is for 4 years, will begin on 07/01/2017, and end on 06/30/2021.**
- **Periodic project status update reports will be submitted July 1 and January 1 of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2021.**

IX. VISUAL COMPONENT or MAP(S):

Restoring and Preserving Savanna Using Bison

Savanna maintained by
prescribed burning

Savanna became forest
due to fire suppression

- **Fire is necessary for restoring oak savanna because it prevents woody encroachment**
- **But fire is insufficient because it kills oak seedlings**
- **We propose that bison may be essential for savanna restoration and preservation**
- **By grazing abundant native grasses, bison would free oak seedlings from competition and decrease the intensity of fires**
- **This could allow oak seedlings to grow to be saplings and then adult trees**
- **Our experiment including 200 acres of savanna plus bison would be the first test of this solution**

X. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS: None

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

Project Title: Evaluating the Use of Bison to Restore and Preserve Savanna Habitat

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

Project Manager: Forest Isbell

Organization: Cedar Creek Ecosystem Science Reserve, University of Minnesota

M.L. 2017 ENRTF Appropriation: \$388,000

Project Length and Completion Date: 4 Years, June 30, 2021

Date of Report: August 13, 2021



ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget 10/19/2017	Amount Spent	Activity 1 Balance	Revised Activity 2 Budget 05/07/2021	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	<i>Restore bison grazing to oak savanna</i>			<i>Experimental</i>			<i>Disseminate results</i>				
Personnel (Wages and Benefits)				\$237,000	\$237,000	\$0				\$237,000	\$0
Postdoctoral Scholar, \$119,000 (82% salary, 18% benefits), 100% FTE each year for 2 years											
3 Undergraduate Student Summer Field and Lab Assistants during year one and 5 Undergraduate Student Summer Field and Lab Assistants during years two and three, each at 25% FTE, \$99,000 (100% salary, 0% benefits)											
2 Temporary and Casual Field Assistant \$19,000 (93% salary, 7% benefits), 17% FTE during year one											
Equipment/Tools/Supplies				\$12,562	\$12,562	\$0	\$20,400	\$20,143	\$257	\$32,962	\$257
Experimental enclosure fencing (\$8,000)											
Experimental supplies (\$4,562)											
Bison education viewing area (\$16,000)											
Education supplies (\$4,400)											
Professional/Technical/Service Contracts	\$89,333	\$89,333	\$0	\$21,667	\$21,658	\$9				\$111,000	\$9
Contract for all materials and labor for construction of perimeter fence and for bulk materials (wire and posts) for experimental fences (10/19/2017)											
Other				\$7,038	\$7,038	\$0				\$7,038	\$0
Soil sample lab analyses for total N and C, nitrate, ammonium (\$7,038)											
COLUMN TOTAL	\$89,333	\$89,333	\$0	\$278,267	\$278,258	\$9	\$20,400	\$20,143	\$257	\$388,000	\$266

