M.L. 2017 Project Abstract
For the Period Ending June 30, 2021

PROJECT TITLE: Cedar Creek Natural Area Wolf Recolonization Assessment
PROJECT MANAGER: Forest Isbell
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2017, Chp. 96, Sec. 2, Subd. 03k as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

APPROPRIATION AMOUNT: $398,000
AMOUNT SPENT: $397,968
AMOUNT REMAINING: $32

Sound bite of Project Outcomes and Results

Minnesota's wolves are expanding southward. A new pack recently recolonized Cedar Creek Ecosystem Science Reserve, which is one of the best-studied ecosystems worldwide. Our project assessed costs (e.g., unwanted impacts on pets and livestock) and benefits (e.g., impacts on biodiversity and ecosystem functioning, educational opportunities) of this unassisted wolf recolonization.

Overall Project Outcome and Results

*Minnesota's wolves (*Canis lupus*) are expanding southward. A new pack recently became established at Cedar Creek Ecosystem Science Reserve (henceforth Cedar Creek), which is one of the best-studied ecosystems worldwide, located just north of the Twin Cities. The goals of our project were to assess costs (e.g., unwanted impacts on pets or livestock) and benefits (e.g., potential enhancement of biodiversity and ecosystem functioning, educational opportunities) of this unassisted wolf recolonization. Our project achieved the following outcomes: (1) determine wolf movements inside and nearby Cedar Creek; (2) experimentally test the impacts of wolves on wildlife, biodiversity, and ecosystem functioning; and (3) provide educational programming to K-12 students and adults. We achieved these goals and outcomes by establishing a network of trail cameras, establishing a new experiment to assess wolf impacts on plants and soils, and bringing K-12 students to Cedar Creek for field trips and developing a website for engagement by citizen scientists. We found that wolf pack produced three litters of pups and grew to include up to 19 wolves, but was then lethally removed by federal trappers after preying on livestock and dogs (Mech et al. 2019). We also found that wolf cues shifted when, but not where, deer used the landscape (Palmer et al. 2021). Deer used risky areas at relatively safe times of the day, when wolves are typically less active, attenuating any cascading effects of wolves on plants or soils. Our Eyes on the Wild citizen science website has thus far engaged 12,625 registered citizen scientists who have provided 7,636,071 classifications of 4,153,218 images generated by our network of trail cameras. These data are being included in several national and global studies of wildlife (e.g., Suraci et al. 2021). More than 7,000 K-12 students and adults engaged in programming related to the project.*

Project Results Use and Dissemination

Project results have been widely disseminated. The Eyes on the Wild website has engaged 12,625 registered users (and thousands more non-registered users), who provided 7,636,071 classifications of 4,153,218 images from our cameras. Project information and results have been widely shared through in-person and online lectures, K-12 school programs and field trips, summer camps, community events, art shows, educational curricula, and local workshops which reached more than 7,000 community members over the lifetime of the

project. Additionally, the project has generated four scientific publications, and regular coverage by local print, radio and television outlets.

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

Date of Submission: August 15, 2021

Final Report

Date of Work Plan Approval: 06/07/2017

Project Completion Date: June 30, 2021

PROJECT TITLE: Cedar Creek Natural Area Wolf Recolonization Assessment

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:	**$398,000**
	Amount Spent:	**$397,968**
	Balance:	**$32**

Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 03k as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

Appropriation Language:
$398,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, Cedar Creek Ecosystem Science Reserve, to assess wolf recolonization impacts on wildlife, biodiversity, and natural resources and provide educational opportunities at Cedar Creek Ecosystem Science Reserve. 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: Cascading Effects of Wolf Recolonization

II. PROJECT STATEMENT:

Minnesota's wolves (*Canis lupus*) are expanding southward, and a new pack recently became established at Cedar Creek Ecosystem Science Reserve (henceforth Cedar Creek), which is one of the best-studied ecosystems worldwide, located just north of the Twin Cities (Fig. 1). Our **GOALS** are to assess the potential costs (e.g., unwanted impacts on wildlife, pets, or livestock) and benefits (e.g., potential enhancement of biodiversity and ecosystem functioning, educational opportunities) of this unassisted wolf recolonization.

OUTCOMES are to:

1. determine wolf movements inside and outside Cedar Creek, including dispersal to establish new packs;
2. measure the impacts of wolves on wildlife, biodiversity, and ecosystem functioning; and
3. provide wolf-related educational programming to K-12 students and outreach for the general public.

We will achieve these goals and outcomes by:

1. using GPS collars to track wolves;
2. establishing a network of trail cameras to assess wolf impacts on wildlife abundances and locations;
3. using existing data and new measurements to assess wolf impacts on plants and soils; and
4. bringing K-12 students to Cedar Creek for field trips and developing a website for citizen scientists.

During 2015, for the first time in approximately a century, a breeding pair of wolves had at least eight pups in a den at Cedar Creek. This new wolf pack is much further south and closer to the Twin Cities than other known packs (Fig. 1). Members of this new wolf pack remained at Cedar Creek, at least through May 2016, as indicated by frequent observations of the wolves, their tracks, and their scat. As members of this pack disperse to establish new packs in coming years, it will be important to assess both the benefits and costs of having wolves so close to a major metropolitan area. Furthermore, Cedar Creek is an ideal site to study the ecological impacts of wolf recolonization because of its decades of comprehensive ecological research, including data from thousands of plots in dozens of multi-decadal studies across the property. The proposed research will combine existing long-term data with new data on the local abundances and spatial distributions of animals, plants, and soil nutrients.

Background:

For many millennia, wolf populations were found throughout the continental United States. By the early 1900's, extensive poisoning had extirpated wolves from all but the northeast corner of Minnesota, reducing the population to a few hundred individuals. Protection by the Endangered Species Act has since allowed Minnesota's wolf population to recover by approximately an order of magnitude, and has allowed wolf populations to expand back into Wisconsin and the upper peninsula of Michigan.

Because Cedar Creek is so data-rich, it provides a unique and ideal opportunity to study the recolonization of this top predator. We have collected 20-30 years of data from dozens of long-term studies that provide a detailed description of community structure and ecosystem function in the absence of wolves. Because these data come from literally thousands of experimental and observational plots distributed across our 21 km^2 landscape, we could use these plots to measure wolf impacts if we can supplement our research efforts with the necessary tools to measure the fine-scale spatiotemporal distribution of wolves and their associated impacts on prey at Cedar Creek.

The loss of top predators from ecosystems worldwide is one of the most pervasive impacts of humans on nature, but it remains unclear whether recovery of predator populations would reverse these impacts or not. Given that apex predators often exert major top-down cascading impacts on herbivores, plants, and soils, it has been suggested that the recovery of predators might be necessary to restore natural systems to their pre-loss state. Alternatively, loss of predators might result in a critical transition to an alternative stable state that persists even if predator populations later recover. Furthermore, predator recovery might also have little impact in some natural systems where community structure and ecosystem functioning are controlled much more by bottom-up resource limitation than by top-down consumer limitation. Thus, it remains unclear whether predator reintroductions will generally result in rapid and dramatic recovery in natural systems.

Top predators were eliminated from many ecosystems worldwide long before ecology existed as a discipline. For example, all investigations at Cedar Creek over the past 75 years have occurred after the loss of its major top predator, the wolf. The unassisted return of wolves to Cedar Creek provides an opportunity to gain a novel and deep understanding of the mechanisms underlying population, community, and ecosystem dynamics, and to predict whether and how the effects of top predators cascade through terrestrial food webs.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2018:
The Snapshot Cedar Creek network of trail cameras (Activity 2) is nearly completely established. Specifically, 20 cameras were purchased and deployed in easily accessible locations along roads and game trails and another 90 cameras were purchased and deployed in a grid that covers each quarter mile of the property, except where there are permanent wetlands or lakes. Only five additional cameras need to be deployed.

A successful search resulted in the hire of a postdoctoral researcher who will begin during spring 2018 (Activities 1, 2, and 3). This new postdoc brings exceptional related research experience and is therefore well-positioned to optimize our Snapshot Cedar Creek project, maximizing its quantity and quality of data, as well as its citizen-science impact.

It appears, based on tracks and scat, that wolf activity has been limited at Cedar Creek during recent months. Trail camera images will more systematically and comprehensively assess wolf abundances across the property. If trail cameras find few wolves infrequently using limited areas of the property, then these cameras will collect important baseline data for the spatial distributions of prey that can later be compared to those observed when wolves are once again more abundant. Alternatively, if the trail cameras frequently detect several wolves, then they will inform collaring efforts (Activity 1).

Several collaborations with the International Wolf Center are underway, helping engage with students and visitors (Activity 4).

Project Status as of July 1, 2018:

More than 315,000 images have now been collected from a total of 125 cameras. The new postdoctoral researcher, Dr. Meredith Palmer, has started to optimize image data and metadata archiving (Activity 2), conduct a new experiment to test potential cascading effects of simulated wolf presence on prey, plants, and soils (Activity 3), and develop the citizen science website (Activity 4). Metadata are now being collected at each camera trap site to document local environmental conditions. These metadata and protocols are currently backed up on the new Google Team Drive and SciNotes (an electronic lab notebook). A project account has also been created on the Minnesota SuperComputing Institute (MSI) servers where the camera trap images are being backed up and can be made online-accessible to collaborators. Images are also being stored on the Team Drive and local hard drives.

There remains a paucity of wolf sign. To remain fiscally efficient, we are awaiting further sign of wolves before commencing collaring efforts (Activity 1). Trail camera images will continue to be collected (Activity 2) and the citizen-science website will soon begin to generate data (Activity 4) that will inform whether field data (Activity 3) should continue to be treated as baseline data and when it is time to begin collaring efforts (Activity 1).

Amendment Request (7/1/2018):
We request a reallocation of our budget to reduce the cost of website development, given that the postdoctoral scholar is capable of developing the website, and to meet higher salary requirements for postdoctoral scholars resulting from the Fair Labor Standards Act. This reallocation would reduce by $10,000 the budget for data and

metadata management and website development (Activity 4) and increase by $10,000 the budget for the postdoctoral scholar salary (Activity 4). We request to save $10,000 on data and metadata management and website development by having the new postdoctoral scholar work with the Research and Learning Technologies (RLT) team in the College of Biological Sciences (CBS) to complete this work. Specifically, we request to reallocate the $70,000 budgeted for a contract to manage data and metadata and to develop the citizen science website (Activity 4) to $60,000 for CBS RLT personnel to manage data and metadata (Activity 4) and $10,000 for the postdoctoral scholar to develop the citizen science website (Activity 4). The postdoctoral scholar has worked with CBS RLT on related projects, including Snapshot Serengeti and Snapshot Safari, and is well-equipped to efficiently complete this work in collaboration with the CBS RLT team. Furthermore, CBS RLT has not only helped develop data management workflows and solutions for related projects, but has also continued to offer long-term support to these projects, which would also be helpful for maintaining the Snapshot Cedar Creek project beyond the first few years of this project. This reallocation is necessary because the Fair Labor 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 need to cut short the postdoctoral research position.

Amendment approved 08/15/2018.

Project Status as of January 1, 2019:

Wolf collaring (Activity 1) has not yet begun, as wolves only occasionally visit the site. Images from the trail cameras are beginning to be analyzed (see Activity 4 status below), and these data will inform the timing and strategy for future collaring.

More than 1,000,000 images have now been collected from a total of 125 cameras (Activity 2). As expected, the number of images is impossible for our staff to view and categorize. Thus, the citizen science website will now be used to fully classify all images (see Activity 4 below). Images are backed up on a hard drive, on Google Drive, and at the Minnesota SuperComputing Institute (MSI).

The postdoctoral researcher, Dr. Palmer, the graduate student, Cristy Portales Reyes, and undergraduate interns tested whether experimental applications of wolf urine affected the behavior of deer with potential cascading effects on plants and soils. Trail camera imagery was used to assess the frequency and timing of deer visits to sites with or without wolf urine. Data were also collected on plants and soils both inside and outside small fences that excluded deer. These measurements included aboveground biomass production, consumption of plant biomass by deer, relative abundances (percentage cover) of plant species, deployment of soil anion and cation probes, and collection of soil cores for quantifying pools of total carbon and nitrogen.

A manuscript submitted by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek remains under consideration for publication. A manuscript by Dr. Palmer that includes the results of the wolf urine experiment is in preparation and will be submitted in early 2019. Dr. Palmer also gave a poster presentation of results from her experiment at the International Wolf Symposium. The *Eyes on the Wild* website (www.eyesonwild.com) is now live and has already engaged more than 1,200 citizen scientists in its first 11 days. The project also now has an active presence on social media, thanks in large part to our new volunteer social media intern. Local media has also covered and promoted the project, with interviews on Minnesota Public Radio (both online and radio) and in local papers.

Project Status as of July 1, 2019:

Wolf collaring (Activity 1) has not yet begun, as wolves continue to only occasionally visit the site. Images from the trail cameras are being analyzed (see Activity 4 status below), and these data will inform the timing and strategy for future collaring efforts. A manuscript submitted by Dr. Mech that details the growth and demise of

the wolf pack at Cedar Creek has now been accepted for publication and is in press at the *Canadian Field Naturalist*.

More than one million images have now been collected, with the most recent check of all cameras in May 2019 retrieving an additional 209,381 images (Activity 2). Throughout the summer, vegetation is being trimmed at cameras that became obstructed by vegetation last year. Meta-data are being collected at all cameras to allow us to account for seasonal differences in vegetation and viewsheds across cameras. This part of the project is now in a maintenance mode, in which images will be collected and camera maintenance will be performed seasonally for most cameras.

A manuscript by Dr. Palmer that includes the results of the wolf urine experiment has been submitted and is in review (Activity 3). It finds that predator-induced trophic cascades can be attenuated when prey use risky places at safe times. For example, in our experiment, deer continued to use the sites where wolf urine was experimentally applied, but visited these sites at times of the day when wolves would typically be less active.

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). In its first six months, through the end of June 2019, the website engaged more than 4,500 registered users to provide 2,611,124 classifications of more than 200,000 images. The project also now has an active presence on social media, thanks in large part to Dr. Potter and our social media work-study student. An additional 1,175 community members participated in in-person programs related to the project at Cedar Creek between January 1, 2019 and July 1, 2019. This includes attendees at a Lunch with a Scientist event led by Dr. Potter and a lecture given by Dr. Mech, visitors who engaged with the project at tabling events at the Science Museum of Minnesota, schoolchildren, and others.

Amendment Request (11/12/2019):
We are unable to complete activity one as proposed (i.e., collaring wolves) because nine wolves were lethally removed from the study area by federal trappers at the beginning of our study, due to verified complaints that the wolf pack had killed livestock and pets, and a wolf pack has not yet recolonized the study site. The growth in the size of the wolf pack from 3 to 19 individuals, as well as the subsequent complaints of depradation and lethal removal of the wolf pack, are fully documented in our recent publication (Mech et al. 2019 Canadian Field-Naturalist). We continue to see sign (i.e., scat, tracks, and trail camera pictures) of one or two wolves passing through the study area, but a pack of wolves is no longer present, which makes the collaring effort unfeasible. We anticipate that a wolf pack will return to the study site in the future, but it is unclear when this will occur and it is extremely unlikely that it will occur before the end of our project.

Given that we are unable to collar wolves, we propose an alternative Activity 1b, which was suggested during peer review of our research addendum and which is consistent with the appropriation language and original aims of our project. Specifically, we propose to establish new experimental fences at the study site to implement a BACI (Before-After-Control-Impact) study design. This BACI study will allow us to directly test the effects of wolves on deer, plants, and soils once a wolf pack returns to the property. Specifically, we propose to establish 15 new fences, designed to exclude deer, thereby experimentally isolating the effects of deer on plants and soils. At each of these 15 fence locations, trail cameras will be established to continuously monitor the frequency of visits by wolves and deer at all times of day and all seasons of the year. At each of the 15 fence locations, 2 plots will also be established, one plot inside the fence and a second plot immediately adjacent to and outside of the fence, for a total of 30 plots, each 7 by 7 m in size. In each of the 30 plots, plant biomass and diversity will be measured and soil cores will be collected and archived. These baseline data for wolves and deer (from trail cameras) and for plants and soils (from collected samples) will serve as the 'Before' measurements in the 'Control' (inside fence) and 'Impacted' (outside fence) plots. In the future, after a wolf pack returns to the study site, these same data for wolves, deer, plants, and soils will be repeated to serve as the 'After' measurements for the BACI study design. This proposed Activity 1b would take advantage of the currently low densities of wolves at the study site, allowing us to collect more rigorous baseline data than we otherwise would

have been able to collect, given that our study began after wolves had recolonized the study site. These baseline data strengthen our study, while remaining consistent with its original aims.

The proposed Activity 1b would differ from Activity 3 in two main ways. First, whereas Activity 3 focuses on analysis of historical and resampled data collected inside and outside of permanent existing fences, Activity 1b would involve establishing new permanent fences. This is especially important given that most of the existing fences are in parts of the property where wolves spent relatively little time. The new fences would be deployed across the entire property, and would include addition of more fences in the parts of the property where wolves were most frequently observed. Second, although we did add some new fences as part of the experiment that was conducted for Activity 3, these fences were temporary and were located in front of a subset of the trail cameras that are a part of the grid. By co-locating these fences with the camera grid, we were able to link the results of Activities 2 and 3; however, these temporary fences cannot remain in front of the grid cameras long-term, as this would permanently obstruct a portion of the viewshed in front of this subset of the grid cameras. Instead, the Activity 1b will establish new permanent fences and trail cameras near a subset of the grid cameras, but not in their viewshed. These fences will not be removed, providing a long-lasting way to rigorously link Activities 2 and 3.

The amount budgeted for personnel ($70,000) would remain unchanged, but effort would be reallocated from collaring wolves to establishing the BACI experiment and sampling the 'Before' data for wolves, deer, plants, and soils. Likewise, the amount budgeted for equipment and supplies ($19,000) would remain unchanged, but would be reallocated from purchasing GPS collars and a telemetry receiver to purchasing fence materials, trail cameras, and supplies for trail cameras, which includes batteries and SD cards. The proposed work can be completed within the originally proposed timeline for the project.

Amendment Approved by LCCMR **1/3/2020**.

Project Status as of January 1, 2020:

A manuscript submitted by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek has now been published in the *Canadian Field Naturalist*. We are now beginning work on our Activity 1b, which has just been approved (see details in the amendment request immediately above). This includes ordering fence materials, trail cameras, camera supplies, as well as hiring for the associated positions.

Our Activity 2 has advanced from establishing the camera network to routine camera checks and maintenance. More than two million images have now been collected (2,003,306), with the most recent check of all cameras in October 2019 retrieving an additional 633,294 images. Classifications of images from the first full year of sampling across the entire grid of cameras are nearly completed. The spatial locations and the seasonal and diurnal timing of activities are becoming increasingly clear for deer, an important prey species for wolves. For example, preliminary results indicate that deer are observed in oak forests throughout the year, but expand and shift their habitat use in the winter season, with frequent observations of them in alder swamps and white cedar swamps. These swamps cover a large portion of our property and the state of Minnesota, providing valuable habitat for deer, especially in the winter when they are frozen and are therefore more accessible. Another winter camera check is currently underway, and will include all cameras, even those that are only safely accessible in winter, when wetlands are frozen.

Our Activity 3 has advanced from data collection to manuscript preparation and submission. A manuscript by Dr. Palmer that includes the results of the wolf urine experiment is currently being revised in response to feedback from reviewers and will soon be resubmitted. This manuscript reports that predator-induced trophic cascades can be attenuated when prey use risky places at safe times. That is, in our experiment, deer continued to use

the sites where wolf urine was experimentally applied, but visited these sites at times of the day (i.e., mid-day) when wolves would typically be less active.

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). In its first year, through the end of 2019, the website engaged 5,381 registered users, and a total of 9,444 unique users when non-registered users were also accounted for, to provide 3,239,172 classifications. To speed up classifications, Dr. Potter developed a new mobile-friendly "Animal or Not?" workflow on the Zooniverse web platform. This mobile-friendly workflow allows users to easily and rapidly separate out the images of greatest interest (i.e., images with non-human animals) from other images that were triggered by movement of vehicles, people, or plants. A total of 6,389 community members have participated in in-person programs related to the project during 2019. This includes K-12 programs at local schools in the Twin Cities Metro area and onsite, lectures and guided classification workshops at Anoka County Library branches, a booth at the MN State Fair as well as at other local environmental events including Earth Day festivals, summer open houses, and county events, an art show of images taken by our cameras on the University of Minnesota campus, adult and family programming at Cedar Creek, and other events. Although some of the programs listed included only a brief introduction to the research project, others provided opportunities for long-term connection and participation. The project also continues to have an active presence on social media, thanks to Dr. Potter and an undergraduate intern, Emma Bublitz. In September, we at Cedar Creek were also pleased to host a site visit by staff and commissioners of the LCCMR.

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:

Substantial progress was made on our new Activity 1b. Specifically, 15 new experimental fences were established to implement a BACI (Before-After-Control-Impact) study that will allow us to directly test the effects of wolves on deer, plants, and soils when a wolf pack returns to the property. The new fences were set at sites spanning a gradient from low to high use by wolves when they were previously present on site. Each of the 15 locations includes a pair of plots, one fenced plot designed to exclude deer and a one adjacent unfenced plot, for a total of 30 plots. A new trail camera was placed at each location to continuously monitor wildlife movement and use of the plots, particularly for deer and wolves. Although the new plots are near existing grid cameras, they no longer obstruct the viewshed. These fences are permanent and will provide a long-lasting way to rigorously link our Activities 2 and 3. All temporary fences from the completed experiment (Activity 3) that were located in front of grid cameras were removed and the camera viewsheds to ensure that the view remains unobstructed.

Along with building these new permanent fences, baseline data were collected as part of the BACI experiment. Soil cores were collected in all plots and will be analyzed for the total carbon and nitrogen content and archived. Aboveground biomass will be harvested in late July to measure productivity. The data collected this summer will serve as the baseline 'Before' measurements in the 'Control' (inside fence) and 'Impacted' (outside fence) plots.

Our Activity 2 continued with routine camera checks and maintenance for the entire camera network. A total of 2,256,602 images have now been collected with the most recent camera survey collecting an additional 253,296 images. In addition to checking the most difficult to access cameras in January 2020, when wetlands were frozen, all deployed cameras were visited during a 2-week period in May. Furthermore, a set of standardized metadata were collected for all cameras during this most recent survey. These metadata include habitat type characteristics that will aid in analyses planned for the fall. We will continue to collect images and perform camera maintenance semiannually or seasonally for cameras that capture large numbers of images. Our data are now being incorporated into national and global meta-analyses of camera trap data that are considering

how the presence of humans affects wildlife distributions and activities. As part of these collaborations, two more manuscripts are now in preparation.

Results from our Activity 3 continue to be disseminated. A manuscript by Dr. Palmer has been resubmitted and is currently undergoing further review. This manuscript finds that predator-induced trophic cascades can be abated when prey use risky places at safe times. In our experiment, deer continued to use sites where wolf urine was experimentally applied but visited these sites at times of the day when wolves are typically less active. The temporary fences and plots associated with Activity 3 were removed this spring to clear the viewshed of all grid cameras. Further data analyses are planned for fall 2020.

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). Thus far, the website engaged 8,238 registered users, and more than 10,000 unique users when non-registered users were also accounted for, to provide 5,458,275 classifications. Due to the pandemic, we have been unable to host in-person programs during spring and summer 2020. However, Dr. Potter and Dr. Palmer gave webinars and invited talks about the project to a variety of audiences, including school groups and the public. The project has been part of a traveling display at Anoka County Libraries during summer 2020. The project continues to have an active presence on social media, thanks to Dr. Potter.

Project Status as of January 1, 2021:

Further progress was made on our new Activity 1b. After previously establishing the 15 new experimental fences and 30 new experimental plots, baseline data have now been collected for the BACI (Before-After-Control-Impact) experiment that will allow us to directly test the effects of wolves on deer, plants, and soils when a wolf pack returns to the property. In each plot, soil cores were collected and aboveground plant biomass was clipped, taken back to the lab, sorted to plant functional group, dried, and weighed. The data collected this summer will serve as the baseline 'Before' measurements in the 'Control' (inside fence) and 'Impacted' (outside fence) plots. We are now fully prepared to assess wolf impacts with 'After' measurements once a pack returns to the site.

Our Activity 2 has advanced from establishing the camera network to routine camera checks and maintenance. More than 3.5 million (3,512,442) images have now been collected, with the most recent camera check in October 2020 retrieving an additional 358,359 images. Classifications of images from the first two years of sampling across the entire grid of cameras are now completed. Another major effort this fall, led by graduate student Hanan Farah, is developing estimates for local abundances from image captures. This is not trivial because cameras often take many pictures of the same individuals, making it challenging to convert numbers of images of a particular species into estimates of its local abundance. A former postdoc on this project, Dr. Palmer, is a leader in testing statistical approaches for these abundance estimates from trail camera images. This fall, Dr. Palmer worked with PI Isbell and a graduate student, Hanan Farah, to begin developing these estimates for two species: (1) deer, which are primary prey of wolves and for which we have estimates of local abundance from multiple other sources of data (i.e., thermal sensors on drones and scat and track counts); and (2) bison, where we have a known herd size against which estimates can be checked. We are testing several statistical approaches for estimating local abundances. After we determine which approaches produce the most accurate estimates, we will then be able to apply these algorithms and statistical approaches to the many other species for which we do not yet have other estimates of local abundances.

Our Activity 3 has advanced from data collection to manuscript preparation and submission to publication. A manuscript led by Dr. Palmer that includes the results of the wolf urine experiment has now been published in the journal *Oecologia*. This manuscript reports that predator-induced trophic cascades can be attenuated when prey use risky places at safe times. That is, in our experiment, deer continued to use the sites where wolf urine was experimentally applied, but visited these sites at times of the day (i.e., mid-day) when wolves would typically be less active. Results from this work were highlighted in a University of Minnesota news release, on

the Eyes on the Wild project blog and on social media channels. We also finished cleaning up the fences and other materials from this study, ensuring that they no longer obstruct the viewshed of our grid camera network.

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). In its first two years, through the end of 2020, the website engaged 9,497 registered users, and many more non-registered users, who together provided 6,737,968 classifications. Volunteers are now able to identify images as quickly as we are able to collect them in the field, thanks to the mobile-friendly "Animal or Not?" workflow that Dr. Potter created on the Zooniverse web platform. Thus far, more than 10,000 community members have participated in directed/in-person programs and experiences related to the project (a subset also participated in online classifications). This includes K-12 programs at local schools in the Twin Cities Metro area and onsite, live virtural programs for afterschool clubs and classrooms, lectures, traveling displays, themed storytimes and guided classification workshops at Anoka County Library branches, a booth at the MN State Fair as well as at other local environmental events including Earth Day festivals, summer open houses, and county events, an art show of images taken by our cameras on the University of Minnesota campus and at the Anderson Center in Red Wing, MN, adult and family programming at Cedar Creek, and other events. Although the pandemic stifled our ability to engage with people in-person in 2020, the citizen science website continues to engage thousands of members of the public. Displays in open community spaces (art galleries, libraries, etc) while Cedar Creek's campus was shut also helped spread the word about the project. Many local K-5 schools used the classification interface and curricula developed by Dr. Potter in their distance learning lessons. The project also continues to have an active presence on social media, thanks to Dr. Potter.

Amendment Request (03/07/2021):
We are requesting $154 be shifted from the personnel to the supplies budget.

- Personnel budget for Activity 1 would be reduced by $154 to a revised budget of $69,846.
- Supplies budget for Activity 1 would be increased by $154 to a revised budget of $19,154.

These changes are requested because the supplies to establish the new BACI experiment cost slightly more than anticipated. The slight reduction of support for personnel will not reduce the scope of work.

Amendment Approved by LCCMR 3/12/2021.

Amendment Request (04/08/2021):
We are requesting $8,371 be shifted from the chemical analyses of soils to the postdoctoral scholar budget.

- Other budget for Activity 3 would be reduced by $8,371 to a revised budget of $3,629.
- Personnel budget for Activity 3 would be increased by $8,371 to a revised budget of $92,371.

These changes are requested because the results reported in a recent publication (Palmer et al. 2021 *Oecologia*), which is a product of Activity 3, indicated that wolves did not alter soil nutrients as hypothesized. Rather than having wolves shift where deer impacted vegetation and soil nutrients, wolves shifted when deer were active. The deer used risky places at relatively safe times of day, when wolves would be less active, but continued to have similar impacts on plants and soil nutrients at all locations. Given these interesting results, we believe the best use of funds would be to have the postdoctoral researcher further analyze and disseminate the vast amount of data flowing in, rather than do further lab analyses on archived soil samples. Without further effort by the postdoctoral researcher, our analyses and archival of data and metadata in a repository will be incomplete. Furthermore, archiving our data and metadata in a repository would provide further opportunities for collaborations on cross-site synthesis projects, which we are already beginning to engage in (e.g., Suraci et al. *In review*).

Amendment Approved by LCCMR 4/15/2021.

Overall Project Outcomes and Results:

Minnesota's wolves (*Canis lupus*) are expanding southward. A new pack recently became established at Cedar Creek Ecosystem Science Reserve (henceforth Cedar Creek), which is one of the best-studied ecosystems worldwide, located just north of the Twin Cities. The goals of our project were to assess costs (e.g., unwanted impacts on pets or livestock) and benefits (e.g., potential enhancement of biodiversity and ecosystem functioning, educational opportunities) of this unassisted wolf recolonization. Our project achieved the following outcomes: (1) determine wolf movements inside and nearby Cedar Creek; (2) experimentally test the impacts of wolves on wildlife, biodiversity, and ecosystem functioning; and (3) provide educational programming to K-12 students and adults. We achieved these goals and outcomes by establishing a network of trail cameras, establishing a new experiment to assess wolf impacts on plants and soils, and bringing K-12 students to Cedar Creek for field trips and developing a website for engagement by citizen scientists. We found that wolf pack produced three litters of pups and grew to include up to 19 wolves, but was then lethally removed by federal trappers after preying on livestock and dogs (Mech et al. 2019). We also found that wolf cues shifted when, but not where, deer used the landscape (Palmer et al. 2021). Deer used risky areas at relatively safe times of the day, when wolves are typically less active, attenuating any cascading effects of wolves on plants or soils. Our Eyes on the Wild citizen science website has thus far engaged 12,625 registered citizen scientists who have provided 7,636,071 classifications of 4,153,218 images generated by our network of trail cameras. These data are being included in several national and global studies of wildlife (e.g., Suraci et al. 2021). More than 7,000 K-12 students and adults engaged in programming related to the project.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: ***Use GPS collars to track wolf movements inside and outside Cedar Creek***
Description:

The project will live-trap wolves, and use GPS collars to track their movements, locations, survival, mortality and predation, inside and outside Cedar Creek. Tracking wolf movements will allow us to determine the full range of wolf activity and impacts inside and outside Cedar Creek, including habitat use within Cedar Creek and dispersal to establish new packs outside Cedar Creek. We will also attempt via the GPS locations to find any new dens, and count and observe new litters and monitor their survival. Assessments will also be made of the wolves' movements around human dwellings. The proposed project will attempt to collar and track two to four wolves annually for at least three consecutive years (2017 - 2019).

Summary Budget Information for Activity 1b:

ENRTF Budget: $ 89,000
Amount Spent: $ 89,000
Balance: $ 0

Outcome	Completion Date
1. *Establish 15 new fences and 30 experimental plots for BACI study*	May 2020
2. *Deploy trail cameras to monitor wolves and deer at each of the 15 pairs of plots*	May 2020
3. *Sample and archive plant biomass and soils from each of the 30 plots*	June 2020

Activity 1 Status as of January 1, 2018:
This activity has not yet begun, as the images from the trail cameras, which are just beginning to be collected (see Activity 2 status below), will inform the timing and strategy for collaring. Before the trail camera images

were available, prior to the start of the project, two previous attempts to collar wolves were made; however, both attempts were unsuccessful.

Activity 1 Status as of July 1, 2018:
Collaring has not yet begun, as there is insufficient evidence that many wolves are currently on site. Images from the trail cameras, which are just beginning to be collected (see Activity 2 status below), will inform the timing and strategy for collaring. To remain fiscally efficient, we do not plan to use these funds until wolves are present at a sufficiently high density to make a collaring effort successful. This may eventually require a request for a no-cost extension of the award duration. Co-PI Mech has led the writing of a manuscript documenting the attempted recolonization of the area by the Isanti Pack, and the associated unwanted impacts of the wolves on pets and livestock (see Dissemination below).

Activity 1 Status as of January 1, 2019:

Wolf collaring has not yet begun, as wolves only occasionally visit the site. Images from the trail cameras (see Activity 4 status below) will inform the timing and strategy for future collaring. To remain fiscally efficient, we do not plan to use these funds until wolves are present at a sufficiently high density to make collaring worthwhile. This may eventually require a request for a no-cost extension of the award duration. If needed, this request will be made during Fall 2019. A pending manuscript submitted by co-PI Mech documents the attempted recolonization of the area by the Isanti Wolf Pack (see Dissemination below).

Activity 1 Status as of July 1, 2019:

Wolf collaring has not yet begun, as wolves only occasionally visit the site. Images from the trail cameras (see Activity 4 status below) will inform the timing and strategy for future collaring. To remain fiscally efficient, we do not plan to use these funds until wolves are present at a sufficiently high density to make collaring worthwhile. This may eventually require a request for a no-cost extension of the award duration. If needed, this request will be made during Fall 2019. A manuscript by co-PI Mech, which documents the attempted recolonization of the area by the Isanti Wolf Pack, has now been accepted for publication (see Dissemination below).

Activity 1 Status as of January 1, 2020:

A manuscript submitted by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek has now been published in the *Canadian Field Naturalist*. We are now beginning work on our Activity 1b, which has just been approved (see details in the amendment request above). This includes ordering fence materials, trail cameras, camera supplies, as well as hiring for the associated positions.

Activity 1b Status as of July 1, 2020:

We established 15 new experimental fences as the beginning of Activity 1b to implement a BACI (Before-After-Control-Impact) study that will allow us to directly test the effects of wolves on deer, plants, and soils when a wolf pack returns to the property. The new fences were set at sites spanning a gradient from low to high use by wolves when they were previously present on site. Each of the 15 locations includes a pair of plots, one fenced plot designed to exclude deer and a one adjacent unfenced plot, for a total of 30 plots. A new trail camera was placed at each location to continuously monitor wildlife movement and use of the plots, particularly for deer and wolves. Although the new plots are still near existing grid cameras, they no longer obstruct the viewshed. These fences are permanent and will provide a long-lasting way to rigorously link Activities 2 and 3. All temporary fences from Activity 3, located in front of grid cameras, were removed and the viewsheds are no longer obstructed.

Along with building new permanent fences, baseline data were collected as part of the BACI experiment. The current low density of wolves at the study site this summer has provided the opportunity to collect rigorous baseline data. Soil cores were collected in all plots and will be analyzed for the total carbon and nitrogen content and archived. Aboveground biomass will be harvested in late July to measure productivity. The sampled biomass will be sorted to live herbaceous biomass, woody biomass, and litter and will be weighed and archived. The data collected this summer will serve as the baseline 'Before' measurements in the 'Control' (inside fence) and 'Impacted' (outside fence) plots. Camera images will be retrieved in the fall and added to the Citizen Science website for classification to obtain data on the frequency of visits to our sites by deer and wolves. In the future, after a wolf pack returns to the study site, these same data for wolves, deer, plants, and soils will be repeated to serve as the 'After' measurements for the BACI study design.

Activity 1b Status as of January 1, 2021:

Further progress was made on our new Activity 1b. After previously establishing the 15 new experimental fences, baseline data have now been collected in all 30 experimental plots of the BACI (Before-After-Control-Impact) study that will allow us to directly test the effects of wolves on deer, plants, and soils when a wolf pack returns to the property. In each plot, soil cores were collected and aboveground plant biomass was clipped, taken back to the lab, sorted to plant functional group, dried, and weighed. This aboveground biomass harvest was completed during peak biomass (when plants are at their peak size for the year), and thus represents the cumulative growth that occurred throughout the growing season. Thus, these peak plant biomass data provide an approximation for aboveground net primary productivity. The data collected this summer will serve as the baseline 'Before' measurements in the 'Control' (inside fence) and 'Impacted' (outside fence) plots. We are now fully prepared to assess wolf impacts with 'After' measurements once a pack returns to the site.

Final Report Summary:
A manuscript submitted by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek was published in the *Canadian Field Naturalist*. We found that wolf pack produced three litters of pups and grew to include up to 19 wolves, but was then lethally removed by federal trappers after preying on livestock and dogs (Mech et al. 2019). Given that we were unable to collar wolves, we successfully completed an approved alternative Activity 1b. Specifically, we established new experimental fences at the study site to implement a BACI (Before-After-Control-Impact) study design. This BACI study will allow us to directly test the effects of wolves on deer, plants, and soils once a wolf pack returns to the property. 'Before' plant and soil samples were collected inside (Control) and outside (Impact) experimental fences. We are now fully prepared to assess wolf impacts with 'After' measurements once a pack returns to the site.

ACTIVITY 2: ***Establish camera trap network to determine wolf impacts on wildlife***
Description:

The proposed project will also establish a network of motion-sensing and heat-sensing camera traps throughout Cedar Creek. This camera trap network will help us determine the impacts of wolves on the local abundances and spatial distributions of Cedar Creek's diverse animal community, which includes wolf prey (e.g., whitetail deer) and competitors (e.g., black bear). Recent advances allow camera trap networks to provide an efficient way to comprehensively sample diverse animal communities and to determine animal responses to the presence and movements of top predators.

Specifically, to determine the impacts of wolf recolonization on herbivorous prey, such as deer and rabbits, and to identify refuges, we propose to establish a network of camera traps throughout Cedar Creek. We will use recent statistical advances that solve former challenges of estimating animal abundances from camera trap data. We will also build on lessons learned from Snapshot Serengeti, which deployed 225 camera traps across a 1,125 km^2 area of the Serengeti and used citizen scientists and experts to reliably classify millions of images. At Cedar Creek, we propose deploying 125 cameras, randomized over an area of 21 km^2. The proposed

camera density at Cedar Creek is more than 25 times greater than that used in the Serengeti, increasing our ability to resolve the abundances and spatial distributions of rare species.

Cameras will be deployed during the first two months of the project, and will operate continuously thereafter. Images will be collected monthly from an easily accessible subset of cameras, and will be collected from all cameras at least once every three months. During camera deployment, a scale size reference will be photographed at three fixed distances away from each camera to later be used as a size reference for animals present in images, and to estimate the extinction of visibility within the camera view. In addition to resampling existing herbivore exclosure studies, plants and soils will be sampled inside and outside new herbivore exclosures, which will be established at each of the camera trap locations.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 143,000
Amount Spent: $ 143,000
Balance: $ 0

Outcome	Completion Date
1. *Establish network of 125 cameras to continuously sample the diverse animal community*	September 2017
2. *Analyze and report local abundance and spatial distribution data from camera traps*	May 2020

Activity 2 Status as of January 1, 2018:

Trail camera locations were identified, based on best practices established by previous related studies. A proposal for conducting this work at Cedar Creek was submitted, reviewed, and approved. Trail cameras were successfully purchased, along with their component batteries, memory cards, and security devices. This purchasing process was slow, taking multiple months, but efficient, given that purchasing services conducted a competitive bidding process to ensure that the best product was obtained for the least cost. Trail cameras were subsequently assembled, programmed, and deployed. Two networks of trail cameras were established: (1) a set of 20 cameras were deployed in easily accessible locations along roads and (2) a set of 90 cameras were deployed in a systematic grid, with cameras spaced 400 meters (approximately one quarter mile) apart. Each type of network has unique advantages and limitations, and thus the combined information from both sets of cameras will allow us to leverage the strengths of both network types. At each location in the grid of trail cameras, posts were installed to systematically mount cameras at a consistent height and bearing, with a standard field of view, ensuring equal sampling effort across locations. Five additional cameras, located in remote parts of the property, have yet to be deployed in the full grid. We are now beginning to revisit cameras to collect images. A successful search resulted in the hire of a postdoctoral researcher who will begin during spring 2018. This new postdoc brings exceptional related research experience from a Snapshot Safari project in Africa. She is therefore well-positioned to optimize our Snapshot Cedar Creek project, maximizing the quantity and quality of its data, as well as the impact of its engagement with citizen-scientists. We have also connected with other researchers who are using a variety of methods, including using small unmanned aircraft equipped with thermal sensors and on-the-ground scat surveys, to estimate deer densities at Cedar Creek. Their data will be compared to those from our trail cameras to obtain and compare several independent estimates of deer densities and distributions.

Activity 2 Status as of July 1, 2018:

Five more trail cameras were deployed in the grid network, including in some of the most difficult-to-access locations. More than 315,000 images have now been collected from a total of 125 cameras. As expected, the number of images is now reaching the point where it is becoming impossible for us to view every image. Thus, the citizen science website will now be needed to fully classify all images (see Activity 4 below). The new postdoctoral researcher, Dr. Meredith Palmer, began her position. Dr. Palmer has started to optimize image data archiving (Activity 2), conduct a new experiment to test potential cascading effects of simulated wolf presence on prey, plants, and soils (Activity 3), and develop the citizen science website (Activity 4). Dr. Palmer

has worked with the other members of the camera trap project to finalize and archive data and metadata collection protocols. Metadata are now being collected at each camera trap site documenting local environmental conditions. These metadata and protocols are currently backed up on the new Google Team Drive and SciNotes (an electronic lab notebook) repositories that Dr. Palmer has created. Dr. Palmer has also created a project account on the Minnesota SuperComputing Institute (MSI) servers where the camera trap images are being backed up and can be made online-accessible to collaborators. Images are also being stored on the Team Drive and local hard drives.

Activity 2 Status as of January 1, 2019:

More than 1,000,000 images have now been collected from a total of 125 cameras (Activity 2). As expected, the number of images is impossible for our staff to view and categorize. Thus, the citizen science website will now be used to fully classify all images (see Activity 4 below). Images are backed up on a hard drive, on Google Drive, and at the Minnesota SuperComputing Institute (MSI). Metadata are collected at each camera when SD cards are changed. Some of the metadata, such as visibility, change from one season to the next as foliage comes and goes. This part of the project is moving into a maintenance mode, in which images will be collected and camera maintenance will be performed seasonally for most cameras, or twice per year at cameras that are only accessible while wetlands and floating bogs are frozen.

Activity 2 Status as of July 1, 2019:

More than one million images have now been collected, with the most recent check of all cameras in May 2019 retrieving an additional 209,381 images. Camera checks include replacing SD cards and batteries, as needed. Throughout the summer, vegetation is being trimmed at cameras that became obstructed last year and meta-data are being collected at all cameras that will allow us to account for differences in vegetation and viewsheds across cameras. Some of the metadata, such as visibility, change from one season to the next as foliage comes and goes. This part of the project is now in a maintenance mode, in which images will be collected and camera maintenance will be performed seasonally for most cameras, or twice per year at cameras that are only accessible seasonally, such as while wetlands and floating bogs are frozen.

Activity 2 Status as of January 1, 2020:

Our Activity 2 has advanced from establishing the camera network to routine camera checks and maintenance. More than two million images have now been collected (2,003,306), with the most recent check of all cameras in October 2019 retrieving an additional 633,294 images. Classifications of images from the first full year of sampling across the entire grid of cameras are nearly completed. The spatial locations and the seasonal and diurnal timing of activities are becoming increasingly clear for deer, an important prey species for wolves. For example, preliminary results indicate that deer are observed in oak forests throughout the year, but expand and shift their habitat use in the winter season, with frequent observations of them in alder swamps and white cedar swamps. These swamps cover a large portion of our property and the state of Minnesota, providing valuable habitat for deer, especially in the winter when they are frozen and are therefore more accessible. We will, of course, need multiple years of data fully classified before we can fully resolve the seasonality of habitat use. A next step will be to estimate local abundances from the image frequencies. We will do this first for deer, given that they are most frequently observed, and for bison, given that their total density is known, and subsequently for other species, as a sufficient number of images become available for other species over time. Throughout the summer and fall, vegetation was trimmed at cameras that became obstructed by vegetation during 2018. Meta-data are also being collected at all cameras to allow us to account for seasonal differences in vegetation and viewsheds across cameras. Another winter camera check is currently underway, and will include all cameras, even those that are only safely accessible in winter, when wetlands are frozen.

Activity 2 Status as of July 1, 2020:

We are continuing routine camera checks and maintenance at our camera network for Activity 2. A total of 2,256,602 images have now been collected with the most recent camera survey collecting an additional 253,296 images. Classifications from images up to October 2019 are now complete and the most recently collected images from May 2020 are in the "Animal or Not?" workflow. Overall, 5,458,275 classifications have been made since the project launched in December 2018. In addition to checking the most difficult to access cameras in January 2020, all deployed cameras were visited during a 2-week period in May through the efforts of a small group of volunteers and interns. Furthermore, a set of standardized metadata were collected for all cameras during this most recent survey. These metadata include habitat type characteristics that will aid in analyses planned for the fall. We will continue to collect images and perform camera maintenance semiannually or seasonally for cameras that capture large numbers of images. Our data are now being incorporated into national and global meta-analyses of camera trap data that are considering how the presence of humans affects wildlife. As part of these collaborations, two more manuscripts are now in preparation. These and other results are forthcoming.

Activity 2 Status as of January 1, 2021:

Our Activity 2 has advanced from establishing the camera network to routine camera checks and maintenance. More than 3.5 million (3,512,442) images have now been collected, with the most recent camera check in October 2020 retrieving an additional 358,359 images. Classifications of images from the first two years of sampling across the entire grid of cameras are now completed. In addition to the data collection in the new BACI experiment and the check of the camera grid, another major effort this fall, led by graduate student Hanan Farah, is developing estimates for local abundances from image captures. This is not trivial because cameras often take many pictures of the same individuals, making it challenging to convert numbers of images of a particular species into estimates of its local abundance. A former postdoc on this project, Dr. Palmer, is a leader in testing statistical approaches for these abundance estimates from trail camera images. This fall, Dr. Palmer worked with PI Isbell and a graduate student, Hanan Farah, to begin developing these estimates for two species: (1) deer, which are primary prey of wolves and for which we have estimates of local abundance from multiple other sources of data (i.e., thermal sensors on drones and scat and track counts); and (2) bison, where we have a known herd size against which estimates can be checked. We are testing several statistical approaches for estimating local abundances. After we determine which approaches produce the most accurate estimates, we will then be able to apply these algorithms and statistical approaches to the many other species for which we do not yet have other estimates of local abundances. Furthermore, a winter camera check is currently underway that focuses especially on the cameras that are only safely accessible in winter, when wetlands are frozen.

Final Report Summary:
In total, 140 cameras were deployed in: (1) a grid of 90 cameras, systematically spaced 400 m apart throughout the property; (2) a set of 35 cameras in strategic locations, such as along game trails and roads; and (3) a set of 15 cameras at locations of experimental deer exclosures. In the first three years of our project, more than 4.1 million images were generated by our network of trail cameras. The cameras are now in maintenance mode, continuing to collect images with routine sampling and maintenance by a team of volunteers. The graduate student and postdoc are continuing to work together on a new manuscript reporting local abundance estimates. To further improve these local abundance estimates, cameras will soon be reprogrammed to capture images at fixed intervals, in addition to continuing to sample when there is motion and heat detection. This will allow estimation of error rates (i.e., how often animals are missed) that are needed for the latest statistical approaches for local abundance estimation.

ACTIVITY 3: ***Resample plants and soils inside and outside exclosures to determine cascading impacts of wolves on biodiversity and ecosystem functioning***
Description:

To determine whether wolf recolonization rapidly affects plant community structure and productivity, we will test for possible cascading impacts of wolves on plant communities and soil nutrients with a BACI (before-after-control-impact) experimental design, using data collected before and after wolf recolonization both inside (control) and outside (impacted) exclosures. These exclosures experimentally eliminate the top-down cascading effects of wolves and mammalian herbivores on plants and soil nutrients, before and after wolf recolonization. This provides a rigorous test of whether, how, and where recolonizing wolves alter plant biodiversity and ecosystem functioning, including plant productivity and nutrient cycling. Specifically, we will resample plants and soils in existing exclosure experiments, which are distributed across our property to test whether, immediately after wolf recolonization, exclosures: (1) increase plant biomass by less than the long-term average homogeneously across our property, which would be consistent with trophic cascade hypothesis; (2) heterogeneously affect plant biomass, with reduced or opposite effect inside than outside refuges, which would be consistent with the landscape of fear hypothesis; or (3) continue to increase plant biomass by approximately the long-term average, which would be consistent with the alternative stable states hypothesis. Previous deer population densities, which have been monitored and modeled by the Minnesota Department of Natural Resources, will be included as covariates.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 96,000
Amount Spent: $ 95,698
Balance: $ 32

Outcome	Completion Date
1. *Resample plant community and soil nutrients inside and outside existing exclosures*	September 2019
2. *Analyze and report plant and soil data from BACI (before-after-control-impact) study*	May 2020

Activity 3 Status as of January 1, 2018:
This activity has not yet begun, as it will be a major effort during summer 2018.

Activity 3 Status as of July 1, 2018:
Given the paucity of wolf sign, as described above, these activities are currently focused on collecting pre-treatment data. The new postdoctoral researcher, Dr. Palmer, has established a new experiment to directly test the potential cascading effects of simulated wolf presence on prey, plants, and soils. Regular application of wolf urine acts as a cue simulating predator presence in specific locations, but without the consumptive effect of predation. This enables us to test the landscape of fear hypothesis ('fear' of predation alone without consumptive effects of predators can result in ecosystem-level changes), by seeing A) whether deer and other herbivores respond to "predator presence" with spatiotemporal avoidance or other behavioral tactics and B) if these responses are strong enough to modify the plant and soil communities. To this end, we deployed herbivore exclosures at 16 grassland camera trap locations in June 2018. Each site has one 4 by 4 m^2 permanent exclosure which will be maintained throughout the duration of the project (multi-year) and one 1 by 1 m^2 moveable exclosure used to quantify herbivore consumption at monthly intervals. Eight of these sites receive weekly applications of wolf urine while the remainder receive control applications of water. The herbivore behavioral component (A) is being quantified using the camera trap imagery while the community effects (B) are being measured by comparing plant communities, productivity, and soil properties inside and outside the exclosures at the end of the growing season (August 2018). Already, one monthly consumption sampling event has taken place. Probes used to measure cation and anion properties of the soils were deployed inside and outside the large exclosures for one month and are currently being analyzed.

Activity 3 Status as of January 1, 2019:

The postdoctoral researcher, Dr. Palmer, the graduate student, Cristy Portales Reyes, and undergraduate interns tested whether experimental applications of wolf urine deterred or affected the behavior of deer, leading to

potential cascading effects on plants and soils. The study design is described above. Data collection included use of trail cameras to assess the frequency and timing of deer visits to sites with or without wolf urine, as well as the duration of visits, age classes, and group sizes of deer. Measurements of plants and soils both inside and outside small fences that excluded deer. Measurements included aboveground biomass production, consumption of plant biomass by deer, relative abundances (percentage cover) of plant species, deployment of soil anion and cation probes, and collection of soil cores for quantifying pools of total carbon and nitrogen. Preliminary analyses suggest that wolf urine had few cascading effects, in part because it merely shifted both when and where deer used sites. That is, deer apparently used risky sites at times of day when wolves would not typically be active. Dr. Palmer is writing a manuscript with these results that will soon be submitted for publication.

Activity 3 Status as of July 1, 2019:

A manuscript by Dr. Palmer that includes the results of the wolf urine experiment has been submitted and is in review (Activity 3). It finds that predator-induced trophic cascades can be attenuated when prey use risky places at safe times. For example, in our experiment, deer continued to use the sites where wolf urine was experimentally applied, but visited these sites at times of the day when wolves would typically be less active.

Activity 3 Status as of January 1, 2020:

Our Activity 3 has advanced from data collection to manuscript preparation and submission. A manuscript by Dr. Palmer that includes the results of the wolf urine experiment is currently being revised in response to feedback from reviewers and will soon be resubmitted. This manuscript reports that predator-induced trophic cascades can be attenuated when prey use risky places at safe times. That is, in our experiment, deer continued to use the sites where wolf urine was experimentally applied, but visited these sites at times of the day (i.e., mid-day) when wolves would typically be less active.

Activity 3 Status as of July 1, 2020:

A manuscript by Dr. Palmer has been resubmitted and is currently undergoing further review. This manuscript finds that predator-induced trophic cascades can be abated when prey use risky places at safe times. In our experiment, deer continued to use sites where wolf urine was experimentally applied but visited these sites at times of the day when wolves are typically less active. The temporary fences and plots associated with Activity 3 were removed this spring to clear the viewshed of all grid cameras. Further data analyses are planned for fall 2020.

Activity 3 Status as of January 1, 2021:

Our Activity 3 has advanced from data collection to manuscript preparation and submission to publication. A manuscript led by Dr. Palmer that includes the results of the wolf urine experiment has now been published in the journal *Oecologia*. This manuscript reports that predator-induced trophic cascades can be attenuated when prey use risky places at safe times. That is, in our experiment, deer continued to use the sites where wolf urine was experimentally applied, but visited these sites at times of the day (i.e., mid-day) when wolves would typically be less active. We also finished cleaning up the fences and other materials from this study, ensuring that they no longer obstruct the viewshed of our grid camera network.

Final Report Summary:
We designed and conducted a field experiment to test the landscape of fear hypothesis: fear of predation, even in the absence of consumptive effects of predators, can result in ecosystem-level changes in biodiversity, productivity, and nutrient cycling. At 32 experimental plots, we crossed two nested treatments: wolf (*Canis lupus*) urine application and herbivore exclosures. We deployed camera traps to quantify how white-tailed deer

(*Odocoileus virginianus*) adjusted their spatiotemporal habitat use, foraging, and vigilance in response to wolf cues and how these behavioral changes affected plant productivity, plant diversity, and soil nutrients. Weekly applications of wolf urine significantly altered deer behavior, but deer responses did not cascade to affect plant or soil properties (Palmer et al. 2021). Deer continued to use risky sites, but did so at the times of day when wolves would typically be less active. Our experiment shows that prey may avoid predators by shifting when, rather than where, they use habitats. Data are now archived in a database and are being disseminated for collaborations on cross-site synthesis projects (e.g., Suraci et al. 2021).

ACTIVITY 4: ***Develop citizen science website and share results with students and visitors***
Description:

A new *Snapshot Cedar Creek* website will be developed to train and utilize citizen scientists to identify wildlife caught on cameras. This website will teach Minnesotans how to identify the wildlife of our state, and will also provide our project with a cost-effective and sustainable method for classifying the large volume of images that will be generated by the camera trap network. Images from Activity 2 will be stored in a database that will populate the *Snapshot Cedar Creek* website, which will be created for citizen scientists to classify each image to species and to report abundance, behavior, and presence of young. Multiple registered citizen scientists will classify each image. An existing algorithm will be used to define consensus on classifications. In Snapshot Serengeti, such classifications were 96.6% accurate for species identifications. Experts will validate a subset of image classifications. Experts will also confirm classification of all images identified as wolves or coyotes (*Canis latrans*) to avoid misclassification of coyotes as wolves, or vice versa.

Results from the proposed project, as well as curriculum previously developed by the International Wolf Center, will be incorporated into the Cedar Creek Education and Outreach program, which serves thousands of K-12 students and visitors each year through field trips to Cedar Creek, classroom visits, and public events and programming. The project will also provide research training for undergraduate and graduate students, and a postdoctoral researcher.

Summary Budget Information for Activity 4:

ENRTF Budget: $ 70,000
Amount Spent: $ 70,000
Balance: $ 0

Outcome	Completion Date
1. *Train and utilize more than 10,000 citizen scientists via the Snapshot Cedar Creek website*	May 2020
2. *Provide on-site educational programming for more than 10,000 K-12 students and visitors*	May 2020

Activity 4 Status as of January 1, 2018:

We are working with purchasing services to conduct a competitive bidding process for the contract to create the citizen science website and manage the associated stream of image data. All required documents have been submitted and are awaiting approvals. This contract position will be hired during spring 2018. In the meantime, we have engaged with collaborators at the International Wolf Center (IWC) to develop a strategy for engaging with our local community. We are currently planning a public event, which will be hosted at Cedar Creek and co-led by the IWC during spring 2018, with the aims of sharing information about this scientific research project, providing a forum for members of the local community to share their perceptions of wolves, and disseminating educational information about wolves, including ways to minimize conflicts between wolves and people's pets and livestock. Also in collaboration with the IWC, a hotline was launched to allow neighbors to report possible wolf sightings and to ask general questions about the presence of wolves in their area. In addition to promoting the hotline on Cedar Creek's website, during in-person visits to the reserve's front desk, and on our main phone line, Cedar Creek staff worked with the IWC to share information about the hotline in multiple local newspapers. IWC outreach staff also led educational programs about wolves at 25 schools in Isanti County. We have also

engaged with the local community around the issues of wolves through a citizen science project called the Cedar Creek Wildlife Survey. One of the important and motivating tasks for this group of 15-20 community members has been documenting the presence of wolves and other canids on Cedar Creek property. The group met 5 times in 2017 to survey Cedar Creek's internal roads for wildlife track and sign and shared their potential wolf track sightings with the project PIs.

Activity 4 Status as of July 1, 2018:
We have identified a highly qualified group at the University of Minnesota for the work originally intended to be used as a contract. This group has recently developed a workflow and successfully completed very similar work for two related projects (Snapshot Serengeti and Snapshot Safari) that are led by co-PI Packer. The new postdoctoral scholar, Dr. Palmer, has started developing a citizen science website on which users can view camera trap photos, identify and count animals in the photographs, and record comments on unique or unusual observations. The website will contain a description of CCESR, a comprehensive background on the wolf project goals (including links to International Wolf Center content), and information on all involved scientists and their individual research interests. The platform will provide content that enables users to identify local wildlife while educating them about the natural history of these local species. A blog, online discussion board, and Facebook page have been created which will be actively updated with progress reports, interesting camera trap photos, and ecology/behavior facts aimed at a general audience when the website goes live (Fall 2018).

On March 10, in collaboration with the International Wolf Center (IWC), we hosted a public event at Cedar Creek that included talks by Isbell (PI on this project) and Mech (co-PI on this project and founder of the IWC), a panel discussion led by Nancy Gibson (co-founder of the IWC), a question and answer session, and an interactive activity for youth led by Misi Stine (Outreach Director, IWC). The event included sharing information about this scientific research project, providing a forum for members of the local community to share their perceptions of wolves, and disseminating educational information about wolves, including ways to minimize conflicts between wolves and people's pets and livestock. The Cedar Creek Citizen Science surveys continue to find wolf sign.

Dr. Palmer and Dr. Potter have organized a meeting with local K-12 teachers and educators to develop course content that uses camera trap images to teach ecological principles and provide opportunities for students to analyze real data. Dr. Palmer has created a camera trapping workshop for high school students, which she used to teach student groups at UMN North Central Research and Outreach Center's STEM day on May 14. Dr. Palmer has also begun to develop an online interactive mapping and graphing widget in collaboration with UMN graduate student Belinda Befort, which will be linked to the Cedar Creek data when available and hosted in conjunction with the citizen science website for use in courses and other educational programming.

Activity 4 Status as of January 1, 2019:

The new *Eyes on the Wild* website (www.eyesonwild.com) has now been developed and, in its first 10 days after going live, has already actively engaged more than 1,200 citizen scientists who have provided more than 200,000 classifications of the first 35,000 images. We named the website *Eyes on the Wild*, rather than *Snapshot Cedar Creek*, to further distinguish this project from previous related projects at other sites (e.g., *Snapshot Serengeti*, *Snapshot Safari*). Palmer and Potter designed the website to train and utilize citizen scientists to identify wildlife caught on trail cameras. The website teaches people how to identify our local wildlife, while also providing our project with a cost-effective and sustainable method for classifying the large volume of images that will be generated by the camera trap network. The more than one million images collected in Activity 2 are now being stored in a database developed by technical staff at UMN's College of Biological Sciences (CBS). From there, images are fed into the *Eyes on the Wild* website, where volunteer citizen scientists then classify each image to species and report the abundance and behavior of wildlife observed in each image. We will continue to work with CBS technical staff to further develop the database and to automate the data pipeline from image collection to upload, processing, storage of images and metadata in the database, import the citizen-science

classifications from the website, execute algorithms to define consensus classifications, and produce maps showing local abundances of each wildlife species.

The project has received media attention by Minnesota Public Radio (https://www.mprnews.org/story/2018/12/26/coyote-weasel-university-of-minnesota-researchers-seek-help-classifying-wildlife-photos) and the *Forum* family of local newspapers. An additional interview has been scheduled with local TV channel KTSP. Potter and Palmer created social media accounts for the project and recruited a social media intern, Emma Bublitz, to engage users of the *Eyes on the Wild* website. Potter and Palmer additionally created and maintain a blog (eyesonthewild.blogspot.com) where they address questions and topics of interest stemming from discussions on the citizen science website. Dr. Palmer disseminated results from her field experiment in a poster presentation at the International Wolf Symposium. Potter developed and delivered middle school level programming about the project for a November homeschool class on wildlife ecology.

Activity 4 Status as of July 1, 2019:

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists. Through the end of June 2019, the website has engaged more than 4,500 registered users to provide 2,611,124 classifications of more than 200,000 images. Classifications have slowed, partly due to the large number of images that only include vegetation, rather than wildlife. To address this, have trimmed vegetation this summer in front of cameras that took many pictures of plants last summer. We also continue to streamline the data pipeline that feeds images into the Zooniverse website and summarizes and stores in a database the metadata that is returned from the Zooniverse website, including the classifications by citizen-scientists, and the metadata collected on each image.

Activity 4 Status as of January 1, 2020:

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). In its first year, through the end of 2019, the website engaged 5,381 registered users, and a total of 9,444 unique users when non-registered users were also accounted for, to provide 3,239,172 classifications. To speed up classifications, Dr. Potter developed a new mobile-friendly “Animal or Not?” workflow on the Zooniverse web platform. This mobile-friendly workflow allows users to easily and rapidly separate out the images of greatest interest (i.e., images with non-human animals) from other images that were triggered by movement of vehicles, people, or plants. A total of 6,389 community members have participated in in-person programs related to the project during 2019. This includes K-12 programs at local schools in the Twin Cities Metro area and onsite, lectures and guided classification workshops at Anoka County Library branches, a booth at the MN State Fair as well as at other local environmental events including Earth Day festivals, summer open houses, and county events, an art show of images taken by our cameras on the University of Minnesota campus, adult and family programming at Cedar Creek, and other events. Although some of the programs listed included only a brief introduction to the research project, many have provided opportunities for long-term connection and participation. The project also continues to have an active presence on social media, thanks to Dr. Potter and an undergraduate intern, Emma Bublitz.

Activity 4 Status as of July 1, 2020:

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). Thus far, the website engaged 8,238 registered users, and more than 10,000 unique users when non-registered users were also accounted for, to provide 5,458,275 classifications. Due to the pandemic, we have been unable to host in-person programs during spring and summer 2020. However, Dr. Potter and Dr. Palmer gave webinars and invited talks about the project to a variety of audiences, including local elementary school classrooms and afterschool clubs, one-on-one “Skype a Scientist” programs, Cedar Creek’s monthly Lunch with a Scientist public lecture series, and lectures to special interest groups including Master Naturalists, Bell Museum volunteers, and science communicators. The project has additionally been part of a traveling display at Anoka County Libraries

during summer 2020, which has driven participation on the *Eyes on the Wild* website. The project continues to have an active presence on social media, thanks to Dr. Potter.

Activity 4 Status as of January 1, 2021:

The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). In its first two years, through the end of 2020, the website engaged 9,497 registered users, and many more non-registered users, who together provided 6,737,968 classifications. Volunteers are now able to identify images as quickly as we are able to collect them in the field, thanks to the mobile-friendly "Animal or Not?" workflow that Dr. Potter created on the Zooniverse web platform, which helps quickly find all the images that have animals and then feeds this subset of images into a second workflow where users identify species and provide information about their behaviors. Thus far, more than 10,000 community members have participated in directed/in-person programs and experiences related to the project (a subset also participated in online classifications). This includes K-12 programs at local schools in the Twin Cities Metro area and onsite, live virtural programs for afterschool clubs and classrooms, lectures, traveling displays, themed storytimes and guided classification workshops at Anoka County Library branches, a booth at the MN State Fair as well as at other local environmental events including Earth Day festivals, summer open houses, and county events, an art show of images taken by our cameras on the University of Minnesota campus and at the Anderson Center in Red Wing, MN, adult and family programming at Cedar Creek, and other events. Although the pandemic stifled our ability to engage with people in-person in 2020, the citizen science website continues to engage thousands of members of the public. Displays in open community spaces (art galleries, libraries, etc) while Cedar Creek's campus was shut also helped spread the word about the project. Many local K-5 schools used the classification interface and curricula developed by Dr. Potter in their distance learning lessons. The project also continues to have an active presence on social media, thanks to Dr. Potter.

Final Report Summary:

The *Eyes on the Wild* citizen scientist interface continues to be popular and well-used. Volunteers are now able to identify images more quickly than we are able to collect them in the field, and we have been able to capitalize on this engagement level to introduce additional workflows to examine more specific research questions. More than 12,600 community members have contributed 7,636,071 classifications of our 4,153,218 images. Additionally, more than 7,000 community members and K-12 students have participated in programming related to the research project. Programs have included K-12 programs at local schools in the Twin Cities Metro area and onsite at Cedar Creek, live and asynchronous virtual programs for afterschool clubs and classrooms, Lunch with a Scientist lectures, traveling displays in our community, themed storytimes and guided classification workshops at Anoka County Library branches, a booth at the MN State Fair as well as at other local environmental events including Earth Day festivals, summer open houses, and county events, and art shows of images taken by our cameras. Collaborations with Master Naturalist volunteers in spring 2021 expanded our library of educational resources related to the project, which helped make the project even more engaging for school groups. *Eyes on the Wild* continues to have an active presence on social media, including facebook and Instagram, and to be featured in newsletters, tours and local media.

V. DISSEMINATION:

Description:

We will communicate results to the scientific community by submitting approximately three peer-reviewed scientific journal articles for publication. We will communicate findings to the general public through the *Snapshot Cedar Creek* website and by offering education and outreach programs on site in collaboration with the International Wolf Center, and we will continue to collaborate with the International Wolf Center to educate the local community about wolves, and particularly to offer tips for minimizing undesirable interactions between wolves and livestock or pets. Data will be archived and disseminated via the Cedar Creek website. We will

continue to communicate with our local County Conservation Officers, Wildlife Services personnel, and other agency representatives involved in wolf conservation and management.

Status as of January 1, 2018:
We have engaged with collaborators at the International Wolf Center (IWC) to develop a strategy for engaging with our local community. We are currently planning a public event, which will be hosted at Cedar Creek and co-led by the IWC during spring 2018, with the aims of sharing information about this scientific research project, providing a forum for members of the local community to share their perceptions of wolves, and disseminating educational information about wolves, including ways to minimize conflicts between wolves and people's pets and livestock. Also in collaboration with the IWC, a hotline was launched to allow neighbors to report possible wolf sightings and to ask general questions about the presence of wolves in their area. In addition to promoting the hotline on Cedar Creek's website, during in-person visits to the reserve's front desk, and on our main phone line, Cedar Creek staff worked with the IWC to share information about the hotline in multiple local newspapers. IWC outreach staff also led educational programs about wolves at 25 schools in Isanti County. We have also engaged with the local community around the issues of wolves through a citizen science project called the Cedar Creek Wildlife Survey. One of the important and motivating tasks for this group of 15-20 community members has been documenting the presence of wolves and other canids on Cedar Creek property. The group met 5 times in 2017 to survey Cedar Creek's internal roads for wildlife track and sign and shared their potential wolf track sightings with the project PIs.

Status as of July 1, 2018:
On March 10, in collaboration with the International Wolf Center (IWC), we hosted a public event at Cedar Creek that included talks by Isbell (PI on this project) and Mech (co-PI on this project and founder of the IWC), a panel discussion led by Nancy Gibson (co-founder of the IWC), a question and answer session, and an interactive activity for youth led by Misi Stine (Outreach Director, IWC). The event included sharing information about this scientific research project, providing a forum for members of the local community to share their perceptions of wolves, and disseminating educational information about wolves, including ways to minimize conflicts between wolves and people's pets and livestock. The Cedar Creek Citizen Science surveys continue to find wolf sign.

Co-PI Mech led the writing and submission of a manuscript documenting the attempted recolonization of the area by the Isanti Pack, the associated unwanted impacts of the wolves on pets and livestock, and the consequent removal of the wolves by the authorities. This paper details changes in the size of the pack, beginning with the breeding pair in 2014, increasing to as many as 19 wolves by 2016, and subsequently decreasing to three individuals by 2017. As the size of the wolf pack grew, complaints arose and were verified that the wolves took as many as three dogs and four calves from 2015 to 2017. In response, the authorities removed a total of nine wolves during 2016 and 2017.

Status as of January 1, 2019:

A manuscript submitted by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek remains under consideration for publication. A manuscript by Dr. Palmer that includes the results of the wolf urine experiment is in preparation and will be submitted in early 2019. Dr. Palmer also gave a poster presentation of results from her experiment at the International Wolf Symposium. The *Eyes on the Wild* website (www.eyesonwild.com) is now live and has already engaged more than 1,200 citizen scientists in its first 11 days. The project also now has an active presence on social media, thanks in large part to our new volunteer social media intern. An additional 392 community members participated in in-person programs related to the project at Cedar Creek between July 1, 2018 and January 1, 2019.

Status as of July 1, 2019:

A manuscript submitted by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek has now been accepted for publication and is in press at the *Canadian Field Naturalist*. A manuscript by Dr. Palmer that includes the results of the wolf urine experiment has been submitted and is in review. The *Eyes on the Wild* website (www.eyesonwild.com) has already engaged more than 4,500 citizen scientists in its first six months. media (facebook page: 514 likes; Instagram page: 111 followers) and via a dedicated research blog (eyesonthewild.blogspot.com), thanks in large part to Dr. Potter and our social media work-study student. An additional 1,175 community members participated in in-person programs related to the project at Cedar Creek and offsite between January 1, 2019 and July 1, 2019. This includes attendees at Lunch with a Scientist event led by Dr. Potter and a lecture given by Dr. Mech, visitors who stopped by tabling events about the project at the Science Museum of Minnesota, schoolchildren and others.

Status as of January 1, 2020:

A manuscript led by Dr. Mech that details the growth and demise of the wolf pack at Cedar Creek has now been published in the *Canadian Field Naturalist*. A manuscript led by Dr. Palmer that includes the results of the wolf urine experiment is now in revision after receiving constructive feedback from reviewers. It will soon be resubmitted. The *Eyes on the Wild* website continues to engage thousands of citizen-scientists. In its first year, through the end of 2019, the website engaged 5,381 registered users, and a total of 9,444 unique users when non-registered users were also accounted for, to provide 3,239,172 classifications. To speed up classifications, Dr. Potter developed a new mobile-friendly "Animal or Not?" workflow on the Zooniverse web platform. This mobile-friendly workflow allows users to easily and rapidly separate out the images of greatest interest (i.e., images with non-human animals) from other images that were triggered by movement of vehicles, people, or plants. A total of 6389 community members have participated in in-person programs related to the project during 2019. This includes K-12 student groups, educators, community members attending lectures and workshops, visitors to booths at the state fair and other local programming, and others. The project also continues to have an active presence on social media. In September, we at Cedar Creek were also pleased to host a site visit by staff and commissioners of the LCCMR.

Status as of July 1, 2020:

A manuscript led by Dr. Palmer has been resubmitted and is currently undergoing further review. The *Eyes on the Wild* website continues to engage thousands of citizen-scientists (Activity 4). Thus far, the website engaged 8,238 registered users, and more than 10,000 unique users when non-registered users were also accounted for, to provide 5,793,812 classifications. Due to the pandemic, we have been unable to host in-person programs during spring and summer 2020. However, Dr. Potter and Dr. Palmer have given webinars and invited talks about the project to a variety of audiences, and engaged the public through a traveling display at local library branches. The project continues to have an active presence on social media, thanks to Dr. Potter.

Status as of January 1, 2021:

The manuscript led by Dr. Palmer has now been published in the journal *Oecologia*. Results from this work were highlighted in a University of Minnesota news release, on the Eyes on the Wild project blog and on social media channels. The *Eyes on the Wild* website continues to engage thousands of citizen-scientists. In its first two years, through the end of 2020, the website engaged 9,497 registered users, and many more non-registered users, who together provided 6,737,968 classifications. Due to the pandemic, we have been unable to host in-person programs during spring and summer 2020. However, Dr. Potter and Dr. Palmer have given webinars and invited talks about the project to a variety of audiences, and engaged the public through a traveling display at local library branches. The project continues to have an active presence on social media, thanks to Dr. Potter.

Final Report Summary:

Data from our trail cameras have now been included in a meta-analysis that included data for 24 mammal species from 61 populations throughout North America (Suraci et al. 2021). Project results have been widely disseminated. The Eyes on the Wild website has engaged 12,625 registered users (and thousands more non-registered users), who provided 7,636,071 classifications of 4,153,218 images from our cameras. Project information and results have been widely shared through in-person and online lectures, K-12 school programs and field trips, summer camps, community events, art shows, educational curricula, and local workshops which reached more than 7,000 community members over the lifetime of the project. Additionally, the project has generated four scientific publications, and regular coverage by local print, radio and television outlets.

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:	$282,000	1 postdoctoral scholar at 100% FTE for 2 years to lead field data collection and analysis efforts and publish papers and to develop the citizen science website ($119,000). 1 graduate student field assistant at 12.5% FTE (half time during summer) for each of 3 years to sample plants and soils ($25,000). 3 undergraduate students at 23% FTE (full time for 12 weeks) during each of 3 summers to assist with collaring wolves, establishing and maintaining cameras, and sampling plants and soils ($67,000). 1 temporary employee at 7.7% FTE (full time for 4 weeks) for each of 3 years to assist with collaring wolves and managing GPS data ($11,000). 1 data analyst to process data and metadata from collars and cameras ($60,000).
Equipment/Tools/Supplies:	$104,000	6 Lotek GPS collars (estimated at $2,900 each), ATS telemetry receiver and datalogger ($1,600) to track wolf movements. 140 Reconyx PC900 Trail Cameras ($550 each, winter ready, motion- and heat-sensing). 2 Handheld GPS units ($1,000 each) to relocate trail cameras. Supplies: camera supplies (batteries, memory cards, security devices, $4,000), fencing materials to mount cameras ($1,000), clippers to sample vegetation ($1,000).
Other:	$12,000	Chemical analyses of soils at UMN Soils Lab (ammonium, nitrate, total soil nitrogen and total soil carbon @$16 per sample x 250 samples per year x 3 years).
TOTAL ENRTF BUDGET:	**$398,000**	

Explanation of Use of Classified Staff: NA

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

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 4.7

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 1.0

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	$212,000	$212,000	
TOTAL OTHER FUNDS:	**$212,000**	**$212,000**	

VII. PROJECT STRATEGY:

A. Project Partners:

Partners receiving ENRTF funding

None

Partners NOT receiving ENRTF funding

Dr. Forest Isbell, Associate Director, Cedar Creek Ecosystem Science Reserve and Adjunct Assistant Professor, University of Minnesota, Project Manager, oversee entire project

Dr. David Mech, Senior Research Scientist, USGS and Adjunct Professor, University of Minnesota, Co-investigator, co-lead Activity 1

Dr. Craig Packer, Professor, Department of Ecology, Evolution & Behavior, University of Minnesota, Co-investigator, co-lead Activity 2

Dr. Caitlin Barale Potter, Education and Outreach Coordinator, Cedar Creek Ecosystem Science Reserve, University of Minnesota, Collaborator, co-lead Activity 4

B. Project Impact and Long-term Strategy:

Results from the project will inform policy decisions regarding the protection of wolves by the US FWS or the management of wolves by the MN DNR, as well as the role of top predators in the restoration of ecosystems by many state and federal agencies and conservation organizations. It will also make major strides in educating the local community and broader general audiences about the role of top predators in ecosystems through the Snapshot Cedar Creek citizen science platform. This project is extremely timely given that expanding wolf populations have for the first time in a century become established on the north side of a major Minnesota metropolitan area. To sustain the proposed project long after 2020, we will seek additional funding from the National Science Foundation (NSF), the National Geographic Society, and other organizations. Cedar Creek is world renowned for conducting high-impact long-term ecological research.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
None		$

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):

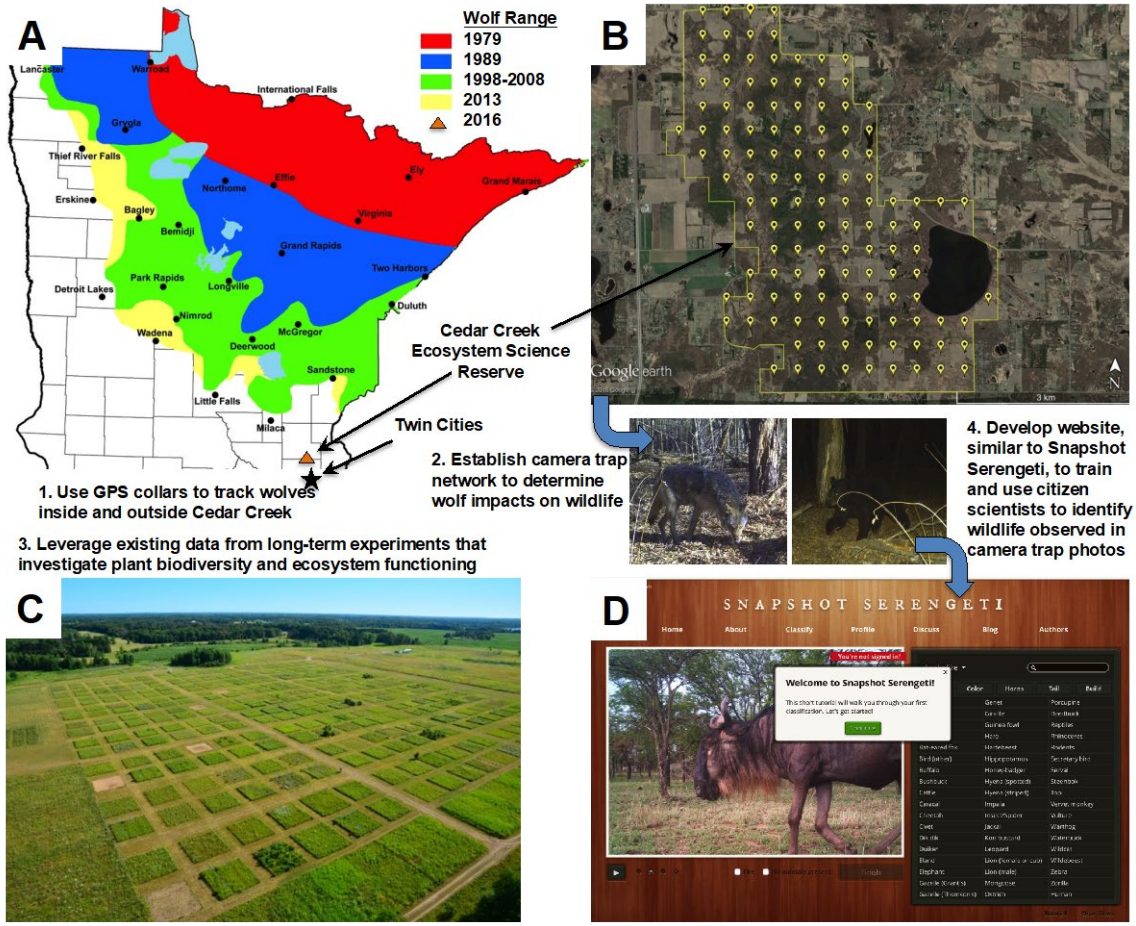

Figure legend: (A) Map showing changes over time in wolf range in Minnesota, as well as locations of Cedar Creek and the Twin Cities (source: MN DNR). (B) Map showing Cedar Creek (source: Google Earth). (C) Photo of one long-term field experiment at Cedar Creek (source: Jacob Miller). (D) Photo of a citizen science website similar to the one we propose to develop (source: www.snapshotserengeti.org).

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

Environment and Natural Resources Trust Fund
M.L. 2017 Project Budget
Project Title: Cedar Creek Natural Area Wolf Recolonization Assessment
Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 03k
Project Manager: *Forest Isbell*
Organization: *Cedar Creek Ecosystem Science Reserve, University of Minnesota*
M.L. 2017 ENRTF Appropriation: $398,000
Project Length and Completion Date: 4 *Years, June 30, 2021*
Date of Report: August 15, 2021

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Revised Activity 3 Budget April 8, 2021	Amount Spent	Activity 3 Balance	Activity 4 Budget 7/1/2018	Amount Spent	Activity 4 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM				***Establish camera trap network***			***Resample plants and soils***							
Personnel (Wages and Benefits)	$69,846	$69,846	$0	$58,000	$58,000	$0	$92,371	$92,339	$32	$70,000	$70,000	$0	$290,217	$32
Postdoctoral Scholar, $127,371 (82% salary, 18% benefits), 100% FTE each year for 2.14 years														
Graduate Student Summer Research Assistant, $25,000 (85% salary, 15% benefits), 12.5% FTE each year for 3 years														
3 Undergraduate Student Summer Field and Lab Assistants, $67,000 (100% salary, 0% benefits), Each position at 25% FTE each year for 3 years														
Temporary and Casual Field Assistant $11,000 (93% salary, 7% benefits), 7.7% FTE each year for 3 years														
Civil Service Employee $60,000 (66% salary, 34% benefits) to manage data and metadata														
Equipment/Tools/Supplies	$19,154	$19,154	$0	$85,000	$85,000	$0							$104,154	$0
140 Reconyx PC900 and 24 Reconyx HP2X Trail Cameras ($550 each, winter ready, motion- and heat-sensing)														
2 Handheld GPS units ($1,000 each) to relocate trail cameras														
Supplies: camera supplies (batteries, memory cards, security devices, $6,054), fencing materials to mount cameras and construct exclosures ($4,900), clippers to sample vegetation ($1,000)														
Other							$3,629	$3,629	$0				$3,629	$0
Chemical analyses of soils at UMN Soils Lab (ammonium, nitrate, total soil nitrogen and total soil carbon @$14.52 per sample x 250 samples per year x 1 year = $3,629)														
COLUMN TOTAL	**$89,000**	**$89,000**	**$0**	**$143,000**	**$143,000**	**$0**	**$96,000**	**$95,968**	**$32**	**$70,000**	**$70,000**	**$0**	$398,000	$32