

2017 Project Abstract

For the Period Ending June 30, 2021

PROJECT TITLE: Effects of Wolf Predation on Beaver, Moose, and Deer

PROJECT MANAGER: Steve K. Windels, PhD

AFFILIATION: Voyageurs National Park

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2017, Chp. 96, Sec. 2, Subd. 03I as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

APPROPRIATION AMOUNT: \$293,000

AMOUNT SPENT: \$288,168

AMOUNT REMAINING: \$4,832

Sound bite of Project Outcomes and Results

Our studies of how, where, and when wolves prey on beavers, moose, and white-tailed deer shed exciting new light on the interactions of these iconic denizens of Voyageurs National Park, Minnesota's only National Park.

Overall Project Outcome and Results

Gray wolves are widely known to prey on adults and fawns/calves of white-tailed deer and moose. Beavers also make up a large portion of wolf diet in areas where beavers are plentiful. Scientists have long pondered how the abundance of beaver prey can affect wolf predation on moose and deer. Voyageurs National Park - Minnesota's *only* National Park – and the surrounding area offers the perfect natural laboratory to learn about wolf hunting behavior and how that affects deer and moose in an area of high beaver densities, as densities can be 2-10x higher here than anywhere else in the state. We captured and GPS-collared 42 wolves in at least 12 different wolf packs to follow their movements and find sites where they killed their prey during the spring-summer-fall period. We identified >1,045 kills, including kills of 335 beavers, 192 adult and 444 fawn white-tailed deer, 1 adult and 1 calf moose, and 65 kills of ≥12 other species including snowshoe hare, bears, muskrats, raccoons, swans, geese, ducks, and other birds. Some of our key findings include understanding how wolf predation can affect beaver abundance, pond creation, and even water storage; better understand how wolves use ambushing behavior and cooperative hunting techniques to hunt and kill beavers; how wolves use roads and trails and areas of recent timber harvest to target and kill deer fawns; and how wolves use a variety of other food sources such as fish and berries to persist in an environment where food can often be scarce. While issues surrounding management of wolves, deer, and moose tend to generate a variety of opinions, better understanding the summer ecology of wolves, especially in a relatively pristine environment such as in Voyageurs National Park, can only improve the ability for Minnesotans to better co-exist with wolves and their prey.

Project Results Use and Dissemination

This collaboration between Voyageurs National Park and the University of Minnesota produced 15 scientific papers and other reports. Our findings have influenced the understanding of wolf behavior and the importance of beavers to forested landscapes in the U.S. and beyond. Research about charismatic species like wolves, beavers, moose, and deer are often very interesting to the general public. We capitalized on that interest by engaging the public through several social media outlets, most notably through a popular Facebook page created by the University of Minnesota. Check out the University of Minnesota's [Voyageurs Wolf Project](#) website for project information.



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

Date of Submission: November 14, 2021

Final Report

Date of Work Plan Approval: 06/07/2017

Project Completion Date: June 30, 2021

PROJECT TITLE: Effects of Wolf Predation on Beaver, Moose, and Deer

Project Manager: Steve K. Windels

Organization: Voyageurs National Park

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Location: Koochiching and St. Louis Counties

Total ENRTF Project Budget:

ENRTF Appropriation: \$293,000

Amount Spent: \$288,168

Balance: \$4,832

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

Appropriation Language:

\$293,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Voyageurs National Park to assess the effects of wolf predation on beaver, moose, and deer in the Border Lakes region. 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: Effects of Wolves on Beavers, Moose, and Deer in the Border Lakes Region

II. PROJECT STATEMENT:

We propose to examine gray wolf hunting behavior in an area with abundant beavers to better understand how the availability of vulnerable beaver prey may affect wolf predation on moose and deer. Gray wolves are widely known to prey on adults and fawns/calves of deer and moose. Beavers also make up a large portion of the diet in areas where beavers are plentiful. Recent studies in Voyageurs National Park (VNP) and surrounding area, where beaver densities are very high, demonstrated that up to 38% of the summer diet is beavers. In other areas of the state beavers are much less a part of wolf diet, generally <5-15%. Moose persist in VNP at low numbers, despite a healthy gray wolf population. Does the high abundance of beavers, a more easily killed prey item than moose, result in lower predation on moose? Likewise, how does the availability of beaver prey affect wolf predation on adult and fawn deer in summer and fall?

Beavers are 2-10x more abundant in VNP than elsewhere in the state because trapping has not been permitted within federally-owned lands in VNP since park establishment in 1975. High beaver densities are generally not tolerated elsewhere in Minnesota because of conflicts they cause from flooding of roads, cutting valuable timber or trees on waterfront property, or stream fisheries. However, a trade-off of lowered beaver densities may be increased predation on moose and deer by wolves.

Voyageurs National Park offers the perfect natural laboratory in Minnesota to learn about wolf hunting behavior in an area where beaver densities can be very high.

The proposed project would build on past and current monitoring and research in VNP related to wolf, beaver, moose, and deer interactions by focusing resources on estimating wolf diet from scats, stable isotopes, and examining kill sites of GPS-collared wolves in VNP for a 3-year study period. Specifically, our project goals are to:

- 1) Determine wolf predation rates on beavers, adult and calf moose, and adult and fawn deer for each of the 6-8 wolf packs that overlap VNP;
- 2) Census beaver populations within each wolf pack in VNP annually; and
- 3) Evaluate the relationship between beaver abundance and wolf predation rates on other prey species such as moose and deer.

Although the proposed research would occur within the boundaries of a U.S. National Park, the results will be applicable anywhere in MN where wolves, beavers, moose, and deer overlap. Project results will also add to the information generated by several other LCCMR-funded projects investigating the cause of moose declines in Minnesota.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *January 1, 2018:*

The project was successfully initiated in 2017. Of note, some field work for the project began before the July 1, 2017 LCCMR start date using in-kind contributions from Voyageurs National Park. This was necessary to ensure that we maximized data collection for the first field season. The University of Minnesota project partners have been very active and some deliverables originating from this LCCMR-funded project (e.g., peer-reviewed science publications; social media content) have already been produced.

Project Status as of *June 30, 2018:*

Voyageurs National Park and University of Minnesota partners continue to work in an effective collaboration, such that the project continues to be on or ahead of schedule for all deliverables. As previously, the University of Minnesota project partners have been very active and deliverables originating from this LCCMR-funded project (e.g., peer-reviewed science publications; social media content) continue to be produced.

Project Status as of *January 1, 2019:*

Voyageurs National Park and University of Minnesota partners continue to collaborate very effectively on the Voyageurs Wolf Project. Our research activities in the second half of 2018 were very successful, with 18 wolves

captured and more than 4,605 potential kill sites visited in all of 2018. We successfully completed a 4th consecutive year of intensive aerial beaver surveys. We published extensively in the peer-reviewed scientific literature, presented at scientific conferences, and our results broadcast in print, radio, and TV media. We also started a Facebook page in December with >12,000 followers at present.

Project Status as of June 30, 2019:

We have captured 27 wolves from 7 packs since spring 2018. This spring we collared 9 wolves from 7 different packs with GPS-collars that take locations every 20 minutes. We have been searching clusters of GPS-locations from these wolves all spring and summer and will continue doing so until the end of October. To date, we have visited 5,985 clusters of GPS locations (i.e., potential kill sites) from collared wolves since April 2018. Including data from our work from 2015-2017, we have visited a total of 8,151 clusters of GPS locations and identified 250 deer fawn kills, 152 beaver kills, 103 adult deer kills, 1 adult moose kill, 1 moose calf kill, and 33 kills of miscellaneous prey (e.g., trumpeter swan, muskrat, woodchuck). When possible, we collected hair samples, bone marrow samples, and teeth at kills so that we can determine the age and condition of prey. We will use this data on wolf predation to estimate predation rates on beavers, moose, and deer.

Amendment Request August 28, 2019

We are requesting funds be shifted from the Personnel, Professional/Technical/Service Contracts, and Equipment/Tools/Supplies budget lines to the contracts budget line.

- Personnel budget will be reduced by \$150,000 to a revised budget of \$6,500
- GPS-satellite data acquisition contract will be reduced by \$49,750 to a revised budget of \$22,250
- A new budget item for \$199,750 for a contract for the University of Minnesota has been added to the Professional/Technical/Service Contracts budget line.

These changes are necessary for two reasons. First, a subcontract with the University of Minnesota for \$150,000 (\$120,000 for PhD student Thomas Gable + \$30,000 for undergraduate research technicians) was intended at the start of the project but was misplaced in the Personnel category instead of Contracts. Second, we overestimated the amount required for GPS-satellite data acquisition but underestimated the amount required by our University of Minnesota subcontractors to complete their deliverables for Activities 1 & 3. This includes an additional semester of funding for PhD student Gable, purchase of additional GPS collars, local travel, and publication costs. The National Park Service has been meeting some of these needs to date with Federal funds but we request a shift in our LCCMR budget to better prepare for the final year of the project.

Project Status as of January 1, 2020:

Voyageurs National Park and University of Minnesota partners continue to collaborate very effectively on the Voyageurs Wolf Project. Our research activities in the second half of 2019 were very successful, with 2 wolves captured and collared. We successfully completed a 5th consecutive year of intensive aerial beaver surveys. We published extensively in the peer-reviewed scientific literature, presented at scientific conferences, and our results broadcast in print, radio, and TV media. Outreach through the Voyageurs Wolf Project Facebook continues to grow.

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 June 30, 2020:

Despite the COVID19 pandemic, we were able to safely conduct fieldwork for the project during the spring of 2020. This spring we collared 5 wolves from at least 3 different packs with GPS-collars that take locations every 20 minutes. We have been searching clusters of GPS-locations from these wolves all spring and summer, and will continue doing so until the end of October.

Project Status as of January 1, 2021:

Voyageurs National Park and University of Minnesota partners continue to collaborate effectively on the Voyageurs Wolf Project. Our research activities in the second half of 2020 were very successful, with 5 wolves captured and collared. We successfully completed a 6th consecutive year of intensive aerial beaver surveys. We published extensively in the peer-reviewed scientific literature, presented at scientific conferences, and our results broadcast in print, radio, and TV media. Outreach through the Voyageurs Wolf Project Facebook, Instagram, and Twitter pages continues to grow.

Overall Project Outcomes and Results:

Gray wolves are widely known to prey on adults and fawns/calves of white-tailed deer and moose. Beavers also make up a large portion of wolf diet in areas where beavers are plentiful. Scientists have long pondered how the abundance of beaver prey can affect wolf predation on moose and deer. Voyageurs National Park - Minnesota's *only* National Park – and the surrounding area offers the perfect natural laboratory to learn about wolf hunting behavior and how that affects deer and moose in an area of high beaver densities, as densities can be 2-10x higher here than anywhere else in the state. We captured and GPS-collared 42 wolves in at least 12 different wolf packs to follow their movements and find sites where they killed their prey during the spring-summer-fall period. We identified >1,045 kills, including kills of 335 beavers, 192 adult and 444 fawn white-tailed deer, 1 adult and 1 calf moose, and 65 kills of ≥12 other species including snowshoe hare, bears, muskrats, raccoons, swans, geese, ducks, and other birds. Some of our key findings include understanding how wolf predation can affect beaver abundance, pond creation, and even water storage; better understand how wolves use ambushing behavior and cooperative hunting techniques to hunt and kill beavers; how wolves use roads and trails and areas of recent timber harvest to target and kill deer fawns; and how wolves use a variety of other food sources such as fish and berries to persist in an environment where food can often be scarce. While issues surrounding management of wolves, deer, and moose tend to generate a variety of opinions, better understanding the summer ecology of wolves, especially in a relatively pristine environment such as in Voyageurs National Park, can only improve the ability for Minnesotans to better co-exist with wolves and their prey.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Determine predation rates on moose, deer, and beavers

Description: Within each of the 6-8 wolf packs (the number varies each year) whose territory overlaps VNP, we will capture and GPS-collar at least 2 wolves/pack. Potential wolf kill sites will be identified from GPS-collar locations (uploaded daily by satellite) and ground crews will examine sites for evidence of species (moose, deer, beaver, other), sex, and age (from teeth and other bones).

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 249,703
Amount Spent: \$ 247,221
Balance: \$ 2,482

Outcome	Completion Date
1. Capture and GPS-collar ≥12 wolves.	November 30, 2018
2. Estimate wolf predation rates on moose, deer, and beaver.	November 30, 2019
3. Final report and activity results submitted.	June 30, 2020

Activity 1 Status as of January 1, 2018:

Some field work for this project started before July 1, 2017, funded by in-kind contributions from Voyageurs National Park. We captured 8 wolves from 4 packs during the spring and summer of 2017. We visited 1,844 clusters of GPS locations (i.e., potential kill sites) from collared wolves from April to October 2017. Including data from a pilot study in 2015 and 2016, we have visited a total of 2,592 clusters of GPS locations and identified 93 deer fawn kills, 59 beaver kills, 52 adult deer kills, 3 snowshoe hare kills, 1 adult moose kill and several kills of

miscellaneous prey (e.g., trumpeter swan, muskrat, woodchuck). When possible, we collected hair samples, bone marrow samples, and teeth at kills so that we can determine the age and condition of prey. We are currently analyzing the data collected from the April-October field season to determine kill and predations rates of wolves on beavers, deer, and moose.

Activity 1 Status as of June 30, 2018:

Fifteen wolves from at least 5 different packs were captured and outfitted with GPS collars since the last status update. Of these, 12 are providing usable data to locate kill sites, or den/rendezvous sites. Summary of kill site data collection is not available at this time but we are on pace to collect more data than was collected in Summer 2017.

Activity 1 Status as of January 1, 2019:

We captured 18 wolves from 7 packs during the spring, summer and fall of 2018. Unfortunately, we were not able to use 10 of the captured wolves for our research because 6 of these wolves were lone wolves that left our study area after capture, 2 wolves had GPS-collars fail right after deployment, and 2 wolves had GPS-collars that did not work correctly. In total, we intensively studied 7 wolves that had 20-min GPS-collars. We visited 4,605 clusters of GPS locations (i.e., potential kill sites) from collared wolves from April to October 2018. Including data from our work from 2015-2017, we have visited a total of 7,151 clusters of GPS locations and identified 188 deer fawn kills, 117 beaver kills, 77 adult deer kills, 1 adult moose kill, and 33 kills of miscellaneous prey (e.g., trumpeter swan, muskrat, woodchuck). When possible, we collected hair samples, bone marrow samples, and teeth at kills so that we can determine the age and condition of prey. We are currently analyzing the data collected from the April-October field season to determine kill and predations rates of wolves on beavers, deer, and moose.

Activity 1 Status as of June 30, 2019:

We have captured 27 wolves from 7 packs since spring 2018. This spring we collared 9 wolves from 7 different packs with GPS-collars that take locations every 20 minutes. We have been searching clusters of GPS-locations from these wolves all spring and summer, and will continue doing so until the end of October. To date, we have visited 5,985 clusters of GPS locations (i.e., potential kill sites) from collared wolves since April 2018. Including data from our work from 2015-2017, we have visited a total of 8,151 clusters of GPS locations and identified 250 deer fawn kills, 152 beaver kills, 103 adult deer kills, 1 adult moose kill, 1 moose calf kill, and 33 kills of miscellaneous prey (e.g., trumpeter swan, muskrat, woodchuck). When possible, we collected hair samples, bone marrow samples, and teeth at kills so that we can determine the age and condition of prey. We will use these data on wolf predation to estimate predation rates on beavers, moose, and deer.

Activity 1 Status as of January 1, 2020:

During the reporting period, we captured and collared 2 wolves within the Cranberry Bay Pack, one of the few packs whose territory boundaries remains completely inside the park. During calendar year 2019 we searched for >4000 wolf location clusters to identify kill sites of prey, including 67 beaver kills.

Activity 1 Status as of June 29, 2020:

This spring we collared 5 wolves from at least 3 different packs with GPS-collars that take locations every 20 minutes. We have been searching clusters of GPS-locations from these wolves all spring and summer and will continue doing so until the end of October. When possible, we collected hair samples, bone marrow samples, and teeth at kills so that we can determine the age and condition of prey. We will use these data on wolf predation to estimate predation rates on beavers, moose, and deer.

Activity 1 Status as of January 1, 2021:

Calendar year 2020 was extremely successful, resulting in the most productive data collection period. We searched 5,300 wolf location clusters to identify kill sites of prey. This was more than 700 clusters searched than in any previous year. We identified 318 wolf ambushing attempts and 314 kills, including 119 beavers, 173 white-tailed deer, and 22 misc. kills.

Final Report Summary:

Voyageurs National Park (VNP) was established in 1975, and VNP/National Park Service (NPS) has been monitoring gray wolf populations intermittently ever since. The most recent monitoring and research effort was started in 2012 by VNP Wildlife Biologist Dr. Steve Windels and his staff. The park's efforts incorporated cooperation from Northern Michigan University (NMU) in Fall 2014. Starting in Fall 2017, University of Minnesota (UMN) cooperators also became involved in the monitoring efforts, and their efforts were partially funded by this LCCMR grant up through June 2021.

Previous studies of wolf predation in VNP have focused on the winter season, when sites where wolves had killed large prey could be easily seen from aerial reconnaissance over snow and ice. Recent advances in GPS technology, however, have made it possible to better understand the summer predation patterns of wolves in the southern boreal forest, which tended to be very difficult to study using older technologies. Former VNP technicians/NMU graduate students Tom Gable and Austin Homkes, in particular, helped develop methodologies during their M.S. projects to find sites where wolves killed small prey like white-tailed deer fawns, beavers, and other small species. Such work laid the groundwork for this LCCMR grant to better understand predation rates on moose, deer, and beavers in and adjacent to Voyageurs National Park during the ice-free period of ~April to October.

Live-trapping wolves to deploy GPS collars is a labor-intensive exercise, sometimes requiring weeks of effort to catch a single wolf in some of the toughest trapping conditions. Voyageurs National Park staff and UMN collaborators had great success capturing wolves in the period of grant performance, with 45 unique wolves (including 2 caught twice) from as many as 12 different packs in and adjacent to Voyageurs National Park during the period April 2017- March 2021. Of these, all 45 wolves were collared and fitted with GPS collars, but only 41 collected data at 20-min intervals that could be used for kill-site identification.

Similarly, finding sites where wolves have killed prey during the ice-free period is very time-consuming. It requires downloading and investigating GPS locations from collar-wolves in near real-time so that potential kill sites, also called clusters, can be located quickly, before prey remains have been wholly consumed by the wolves or other scavengers. Moreover, kill sites are often far removed from easy access points by vehicle or boat, requiring long hikes in a challenging environment to find them for data collection.

During the period ice-free periods of April-October 2017-2020, VNP staff and UMN cooperators investigated >17,000 clusters in and adjacent to VNP. This represents >9,000 hours of search time over the period 2018-2020 alone. We identified >1,045 kills, including kills of 335 beavers, 192 adult and 444 fawn white-tailed deer, 1 adult and 1 calf moose, and 65 kills of ≥ 12 other species including snowshoe hare, bears, muskrats, raccoons, swans, geese, ducks, and other birds. This dataset, in combination with data collected from 2015-2016, represents some of the most detailed data ever collected about the summer predation behavior of wolves, and the insights generated from this work have the potential to influence our understanding of wolves and other predators in Minnesota and beyond.

Wolves have long been known as cursorial predators, that is, they typically chase their prey. For example, this is generally how wolves hunt and kill ungulate prey like white-tailed deer, moose, elk, caribou, etc. Work by VNP staff and graduate student Tom Gable - in the time before the start of this LCCMR grant in 2017 - helped to uncover how wolves hunted a different kind of prey, the American beaver. Wolves used a strategy of waiting in areas where they were most likely to encounter and attempt to kill unsuspecting beavers, such as near feeding trails, dams, or lodge sites. Other work at that time using scat-based analyses illustrated how important beavers

could be to wolves in the VNP area. The amount of beaver biomass in wolf diets varied between wolf packs and over the course of the growing season (April-October), but could be as high as 60% for some packs in some months.

Even after these scientific advances, there was still a lot unknown about the interactions between beavers and wolves in the southern boreal forest at the time of the start of this LCCMR project. As a next step, we undertook an extensive review of the state of knowledge about wolf-beaver interactions in the world. The resulting paper, titled “The Forgotten Prey of an Iconic Predator...”, provides an extensive review about the importance of beavers in wolf diets across the two species range; what is known about wolf predation behavior on beavers; and how wolf predation may influence beaver populations, or vice versa, how predation on beavers may influence wolf populations. This paper was the first of 6 chapters in Tom Gable’s Ph.D. dissertation.

Another important paper from Tom Gable’s Ph.D. dissertation was the first to provide kill rates (or, how many prey does a predator kill per unit time) and predation rates (or, what proportion of the prey population is killed by the predator) of wolves on beavers, aptly titled “Kill rates and predation rates of wolves on beavers.” This study focused on 1 GPS-collared wolf from a single pack, which we documented killing 22 beavers during the ice-free season. Extrapolated for the whole pack, we estimated that this pack killed 88 beavers during this one season, resulting in kill rates of 0.085–0.095 beavers/wolf/day. However, we concluded that the estimated predation rate of 38-42% of the beaver population within that wolf pack’s territory that was killed that season was likely biased high but was still reflective of a relatively high predation rate for that one territory that season. Despite the relatively high predation rate, the beaver population within that wolf territory actually increased by the next season, leading us to suggest that 1) some wolves and wolf packs likely do kill lots of beavers at times, and 2) beaver populations appear robust to lower levels of predation.

Other work highlighted the importance of wolf predation on dispersing beavers, and the subsequent impacts that can have on the creation and retention of individual beaver ponds. Wolves, on average, killed 0.021 dispersing beavers per wolf per day, which equated to approximately 4.5 dispersing beavers per wolf per year. The effect of the predation on dispersing beavers was eye-popping. In total, we estimated that wolves altered the establishment of ~88 ponds per year and the storage of ~194,000 m³ of water per year. This paper, titled “Oversized effect of predation: wolves alter wetland creation and recolonization by killing ecosystem engineers”, rightly received lots of media attention due to its novel approach to understanding how top-down effects of wolf predation on the ecosystem engineering beaver can have significant impacts to the landscape.

Considerable effort was also spent to better understand the behaviors wolves use to hunt and kill beavers, with the results comprising the other 3 chapters (and subsequent publications) of Tom Gable’s Ph.D. dissertation. One of the only known videos of a wolf attacking and killing a beaver was analyzed to describe how beavers defend themselves when attacked by wolves and how wolves hunt beavers, highlighted in a paper titled “Do wolves ambush beavers? Video evidence for higher-order hunting strategies”. The reviewed video evidence confirmed that wolves do indeed hunt and kill beavers by surprising and ambushing them.

Another paper, “Wolves choose ambushing locations to counter and capitalize on the sensory abilities of their prey”, took a much more detailed look at where and how wolves ambush beavers, building off the earlier work published in 2016. This study documented >700 beaver hunting attempts by wolves, and 214 cases where wolves successfully killed a beaver. Key findings from this paper were that 1) in almost 90% of hunting attempts, wolves chose ambush locations where the beavers keen sense of smell was not likely to detect them; 2) conversely, wolves took advantage of the generally poor eyesight of beavers by positioning themselves close (<15’ or 5m) to where they expected the beaver to travel; 3) 65% of wolf hunting attempts occurred at feeding sites; and 4) while wolves spent considering time attempting to ambush beavers at feeding sites, only 32% of kills occurred there, suggesting that opportunistic encounters make up a larger fraction of successful wolf kills than previously thought.

The last chapter of Tom Gable's dissertation, a paper titled "Wolves use cooperative ambush strategies to hunt beavers", documented the behavior of a mated pair of wolves – both with GPS collars - working together to ambush beavers on 8 different occasions, of which 3 were successful. Generally, these wolves hunted beavers individually but ~15% of the time their beaver hunting attempts were together. Combined with the previously described work on wolf hunting behavior, these studies provide new insights into how large carnivores like wolves hunt and kill their prey.

Another significant area of research focused on wolf predation behavior on white-tailed deer fawns, for which former VNP staff and NMU graduate student Austin Homkes focused his M.S. thesis, titled "Wolf Selection of Human-Modified Linear Features and Cover Types When Hunting and Killing White-Tailed Deer Fawns." Field work that contributed towards this thesis project started in 2015 but continued into 2019, after this current LCCMR grant period had started. As described above, clusters of GPS locations were searched for evidence of successful kills of deer fawns. Kill sites of 217 fawns by 12 different wolves during the period 2016-2019 were analyzed. The earliest date a wolf killed a fawn was 23 May, with the greatest number of kills occurring during 17 June -22 June. Fawns were most often killed between 8am-12pm, with the fewest kills occurring between 2am-4am. Wolves were more likely to hunt and successful kill fawns close to linear features such as logging roads and ATV trails, and also closer to recent forest cuts. Combined, these data have the potential to be very informative about forest management activities, such as clear-cutting and road creation, can affect survival of white-tailed deer fawns in the northern forests of Minnesota and beyond. A manuscript detailing the findings of this thesis are in preparation at present.

When analyzing some of the data from kill sites of deer fawns obtained during this study, some interesting behaviors were observed about how wolves may be hunting and killing more than one offspring from a single doe in close succession. Additional analyses are in process, including some analyses of genetic material, that may shed more light on how often this phenomenon is occurring.

In what some may find as a surprising result, we only documented 2 kills of moose by wolves during the ice-free period of the 4 years of this grant period. Similarly, we did not document any wolf-killed moose during the first 2 years we studied wolf predation in 2015-2016. We did find more evidence of wolves scavenging, but not killing, dead moose including road-killed moose. Data from other sources corroborates this very low predation rate of wolves on moose in the Voyageurs National Park area. First, during a study of GPS-collared moose from 2010-2017 by VNP staff and other cooperators, we documented overall very high annual survival rates of adult moose, certainly higher than other areas of Minnesota moose range. Ten of the 22 moose we collared during the study were confirmed to have died, and of these only 5 died during the April-October ice-free period. Wolf predation was considered a possible cause of death in only 1 of these 10 (but only because the carcass was heavily scavenged, and we could also not rule out health-related factors). Second, recent independent assessments of wolf diets in the VNP area using scat analysis (including two studies authored by VNP staff and UMN cooperators) concluded that moose represented <10% of the biomass consumed by wolves during the ice-free period, of which the largest portion was likely from scavenging. Previous studies of wolf predation on moose in the VNP area have shown that predation during the winter period was also very low.

The low numbers of wolf-killed moose in this area during this grant period is also a function of the low moose density that occurs in and adjacent to Voyageurs National Park. Densities in the eastern 2/3 of the Kabetogama Peninsula, a 300 km² (116 mi²) roadless area in the middle of the park, are between 0.10-0.15 moose/km², while densities in the rest of the park and the areas to the south are <0.05 moose/km². These densities are 25-75% less than densities elsewhere in the core moose range in N.E. MN. In other words, there are fewer moose targets to start with in the Voyageurs National Park area for wolves to even target.

In addition to providing information towards Activities 1 and 3 in the report, data on wolf movements and predation events collected during April 2017- March 2021 have been used to inform other research, including 12 peer-reviewed publications and 3 reports/theses/dissertations listed in the deliverables section. These include

interesting observations about how wolves hunt for fish during spring spawning runs, wolves killing swans and otters, and wolves eating berries during the mid-summer period when other prey are unavailable. Data collected during the project period was also used to help refine methods for identifying homesites (i.e., den or rendezvous sites) of wolves, and to describe long-distance dispersal behavior in wolves. Lastly, data collected during the project period has been used to inform VNP and Minnesota DNR about the status of wolves in the VNP area, including number and size of individual packs, and survival and cause of death (sometimes) for individual collared wolves.

As described above, the amount of data collected both before (2015-2016) and during (April 2017- March 2021) the project period is immense. We have produced and disseminated a large amount of high quality science using the data collected, but, not surprisingly, there is still a lot more that can be done. Of note, more quantitative analyses of kill rate and predation rates on white-tailed deer are needed, particularly on the adult animals. Likewise, there are also pending analyses about vulnerability of deer and beavers to wolf predation varies as a function of age and sex.

Conducting research in the water-based environment of VNP is challenging, and consequently expensive. In-kind contributions from VNP for Activity 1 are conservatively estimated to exceed \$350,000, which mainly came in the form of paid staff time for field work, project administration, and boat/vehicle maintenance; boat and vehicle usage and gas; use of trapping and collaring equipment; GPS collars and data acquisition; field supplies, including pharmaceuticals for capture; office space and computer use; and lab and storage space. In-kind contributions from other partners, specifically the University of Minnesota and Northern Michigan University, were important, but estimates were not available at the time of this final report.

ACTIVITY 2: Census beaver populations within each wolf pack in VNP

Description: Annual fall beaver cache surveys will be completed using fixed-wing aircraft. Each active beaver lodge will be identified and mapped using real-time GIS software. Beaver abundance data gathered for this project can be related to other beaver population work done in VNP from the 1950s-present.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 24,432
Amount Spent: \$ 24,432
Balance: \$ 0

Outcome	Completion Date
1. Annual estimates of beaver abundance in each wolf pack.	November 30, 2019
2. Final report and activity results submitted.	June 30, 2020

Activity 2 Status as of January 1, 2018:

We conducted aerial beaver censuses in all known wolf pack territories (i.e. packs where at least 1 wolf was collared) in and around Voyageurs National Park in October 2017. Tom Gable, a PhD student at University of Minnesota, conducted the survey with Department of the Interior pilot Jim Hummel. All surveys were flown in a 2-seat tandem Top Cub at 600–700 ft. above the ground at a speed of approximately 70 mph. Active beaver colonies were identified based on the presence of a food cache next to a lodge, fresh cuttings, or fresh mud on a lodge or dam. During the survey, Tom Gable recorded all active beaver lodge locations using real-time Geographic Information Systems software on a computer. The census was completed in 29.5 hours of flight time over the course of 7 days. We are currently working on estimating the beaver density in wolf pack territories using the combination of our beaver census results and our wolf location data. That is, we are delineating wolf pack territories using statistical software and wolf locations, and then determining how many beaver colonies we identified in those territories during our census. By doing this we will get a beaver density estimate for each pack territory which will allow us to compare beaver densities among different pack territories. Our census in 2017 marks the 3rd consecutive year we were able to conduct a census of all beaver lodges in known wolf pack

territories in and around Voyageurs National Park. In the 2017 census, we documented 1,441 active beaver lodges. Based on preliminary analysis, this appears to be a slight increase from the census results in 2016.

Activity 2 Status as of June 30, 2018:

We are currently planning for the aerial beaver census for October 2018, including securing aircraft and pilots.

Activity 2 Status as of January 1, 2019:

We conducted an aerial beaver survey throughout most of the Greater Voyageurs Ecosystem (GVE) October 21-24, 2018. Tom Gable, a PhD student at University of Minnesota, conducted the survey in Voyageurs National Park's aircraft, piloted by National Park Service pilot Jim Hummel. All surveys were flown in a 2-seat tandem Top Cub at 600–700 ft. above the ground at a speed of approximately 70 mph. Active beaver colonies were identified based on the presence of a food cache next to a lodge, fresh cuttings, or fresh mud on a lodge or dam. During the survey, Tom Gable recorded all active beaver lodge locations using real-time Geographic Information Systems software on a computer. The survey was completed in 23.9 hours of flight time over the course of 4 days. Our surveys in 2018 marks are the 4th consecutive year we were able to conduct a census of all beaver lodges in known wolf pack territories in and around Voyageurs National Park. In the 2018 survey, we documented >1,400 active beaver lodges, which based on preliminary analysis, this appears to be slightly lower than 2017.

Activity 2 Status as of June 30, 2019:

We conducted aerial beaver censuses in all known wolf pack territories (i.e. packs where at least 1 wolf was collared) in and around Voyageurs National Park in October 2017 and 2018. Tom Gable, a PhD student at University of Minnesota, conducted the survey with Department of the Interior pilot Jim Hummel. Our census in 2018 marked the 4th consecutive year we were able to conduct a census of all beaver lodges in known wolf pack territories in and around Voyageurs National Park.

Activity 2 Status as of January 1, 2020:

We conducted an aerial beaver survey throughout most of the Greater Voyageurs Ecosystem (GVE) October 24-29, 2019. Tom Gable, a PhD student at University of Minnesota, conducted the survey in Voyageurs National Park's aircraft, piloted by Department of Interior pilot Jim Wittkop. Our surveys in 2019 marks the 5th consecutive year we were able to conduct a census of all beaver lodges in known wolf pack territories in and around Voyageurs National Park.

Activity 2 Status as of June 29, 2020:

We are currently planning for the aerial beaver census for October 2020, including securing aircraft and pilots.

Activity 2 Status as of January 1, 2021:

We conducted an aerial beaver survey throughout most of the Greater Voyageurs Ecosystem (GVE) October 16-19, 2020. Tom Gable, a PhD student at University of Minnesota, conducted the survey in Voyageurs National Park's aircraft, piloted by National Park Service pilot Scott Taylor. Our surveys in 2020 marks the 6th consecutive year we were able to conduct a census of all beaver lodges in known wolf pack territories in and around Voyageurs National Park.

Final Report Summary:

Voyageurs National Park (VNP)/National Park Service (NPS) has been conducting surveys of beaver populations in some form since 1984, including aerial surveys of beaver sign conducted in late fall. Survey protocols are straightforward, with the observer recording locations of beaver lodges and documenting activity based on the appearance of a food cache in front of the lodge, fresh mud on the lodge or dam, or feeding trails or fresh cut

trees. Recent improvements in the survey include recording data using real-time GIS software on tablet in the computer, which improves positional accuracy of locations and flight pattern efficiency to assure complete coverage of the study area. Data can be used to track changes in population abundance, distribution, activity of individual pond sites, or even food availability for beavers.

In 2015-2016, NPS staff and collaborators completed a full census of beaver activity inside the boundaries of Voyageurs National Park. Additionally, for the first time, we also surveyed areas outside of the park that overlapped with territories of GPS-collared wolves. Similar aerial surveys continued during the successive 4 years (2017-2020) of this LCCMR project, in collaboration with Tom Gable at the University of Minnesota. The number of individual active lodges recorded for the entire study area each year exceeded 1,350, representing arguably the highest densities of beavers in the Lower 48 States.

Previous beaver research and monitoring conducted by VNP/NPS since 1984, and more specifically work conducted since 2004 by VNP Wildlife Biologist Dr. Steve Windels, already created one of the longest and most extensive studies of beavers in the world, informally titled the BVR: Beavers.Voyageurs.Research. The additional 4 years of extensive beaver surveys conducted during the period of performance for this LCCMR grant are an important contribution to this long-term project.

In addition to providing information towards Activities 1 and 3 in the report, beaver population data collected during 2017-2020 has been used to inform other research, including 6 peer-reviewed publications listed in the deliverables section.

Safely conducting manned aviation missions is an expensive endeavor, requiring extensive pilot training and aircraft maintenance. Observers require such training, too. This current LCCMR grant to VNP provided \$15,000 to help pay the hourly flight rate for the 2017-2019 beaver surveys, with VNP covering all of the flight time for 2020. Additionally, Voyageurs National Park expends >\$80,000 annually to operate our aviation program. We estimate total in-kind contributions from VNP/NPS for Activity 2 for 2017-2020 exceeds \$50,000.

ACTIVITY 3: Evaluate relationship between beaver abundance and wolf predation on moose and deer

Description: Beaver abundance varies across the VNP landscape and therefore varies between wolf packs. We will evaluate how differences in the abundance of beavers can affect wolf predation rates on moose and deer of different sex and age classes (fawn/calves, yearlings, prime adults, old adults).

Summary Budget Information for Activity 3:

ENRTF Budget: \$ 18,865
Amount Spent: \$ 16,515
Balance: \$ 2,350

Outcome	Completion Date
1. Modeling/analysis of predation rates and prey abundance.	November 30, 2019
2. Final report and management recommendations detailing linkages between beaver abundance and wolf predation rates on moose and deer.	June 30, 2020

Activity 3 Status as of January 1, 2018:

We are still analyzing the data collected from the 2017 field season regarding wolf kill and predations rates of moose and deer. We are also exploring different analytical/modeling approaches that will be used to analyze the completed data set after the 2019 field season.

Activity 3 Status as of June 30, 2018:

We will analyze the relationship between beaver abundance and wolf predation on moose and deer using the data collected for objectives 1 and 2. As mentioned above, we are still analyzing the data collected from the 2018 field season regarding wolf kill and predations rates of moose and deer. Once we have these estimates, we will estimate the beaver abundance in each of these pack's territories. Once we have estimates of wolf pack kill rates of moose and deer, and estimates of beaver abundance in these wolf pack territories, we can examine whether higher beaver densities lead to lower kill rates of moose and deer. Ultimately, to address this question, we will need to wait until the end of the 2019 field season as we need to increase of sample size markedly to examine any pertinent ecological trends.

Activity 3 Status as of January 1, 2019:

We are still analyzing the data collected from the 2017-2018 field seasons regarding wolf kill and predations rates of moose and deer, and organizing data collected during this status period. We are also exploring different analytical/modeling approaches that will be used to analyze the completed data set after completion of the 2019 field seasons.

Activity 3 Status as of June 30, 2019:

We will analyze the relationship between beaver abundance and wolf predation on moose and deer using the data collected for objectives 1 and 2. Once we have these estimates, we will estimate the beaver abundance in each of these pack's territories. Once we have estimates of wolf pack kill rates of moose and deer, and estimates of beaver abundance in these wolf pack territories, we can examine whether higher beaver densities lead to lower kill rates of moose and deer. Ultimately, to address this question, we will need to wait until the end of the 2019 field season as we need to increase our sample size to examine any pertinent ecological trends.

Activity 3 Status as of January 1, 2020:

Data analysis continues towards the completion of Activity 3.

Activity 3 Status as of June 29, 2020:

We will analyze the relationship between beaver abundance and wolf predation on moose and deer using the data collected for objectives 1 and 2. Once we have these estimates, we will estimate the beaver abundance in each of these pack's territories. Once we have estimates of wolf pack kill rates of moose and deer, and estimates of beaver abundance in these wolf pack territories, we can examine whether higher beaver densities lead to lower kill rates of moose and deer. Given the extension received for the project, we will incorporate data collected during 2020 field season to increase our sample size to examine any pertinent ecological trends.

Activity 3 Status as of January 1, 2021:

Final data analysis and report writing continues towards the completion of Activity 3.

Final Report Summary:

In our review paper "The forgotten prey of an iconic predator: a review of gray wolf-beaver dynamics" we addressed how areas with abundant beaver populations may indirectly influence wolf predation on ungulate species such as moose and white-tailed deer. One of three scenarios is most likely: 1) high beaver populations can buffer ungulate populations from wolf predation, thereby decreasing wolf predation on ungulate populations; 2) high beaver populations may support a higher wolf population, which can then increase wolf predation on other ungulates, also known as apparent competition; or 3) there is no relationship between beaver populations and ungulate predation.

Beaver abundance did vary across most of the wolf packs we studied during 2017-2020 study period for this grant. However, we observed such low moose predation by wolves during the (only 1 adult and 1 calf moose

total!), we will not be able to address how beaver abundance may have influenced predation on moose. In other words, moose predation was extremely low everywhere, regardless of beaver abundance. Other analyses investigating the relationship between beaver abundance and predation on white-tailed deer are in progress, specifically how kill rates may vary by sex or age as beaver abundance changes at the territory and population scales. In-kind contributions towards Activity 3 have been minimal to date, in part because analyses for this activity are on-going.

V. DISSEMINATION:

Description: Project progress and results will be shared with the public in a number of ways. While field work is ongoing, outreach will include newsletter articles; articles in local, regional, and state newspapers; posts on Voyageurs National Park's Facebook page; presentations to interested stakeholder groups (e.g., Minnesota Deer Hunter's Association or Isaac Walton League of Duluth); presentations at scientific conferences; and peer-reviewed literature in quality journals.

Status as of January 1, 2018:

List of Dissemination/Outreach during reporting period:

- Public presentations:
 - Participated in an event for the Voyageurs National Park Association at Bauhaus Brewing Company in Minneapolis. We set up a table with photographs, information, and props from the project and talked with several members of the public about our research.
 - Gable T.D. 2017. How do wolves hunt beavers? Presentation/talk for International Wolf Center volunteer appreciation dinner, December 14, 2017.
- Print media
 - Gable, T.D. 2017. What is a rendezvous site? Wolf Park Newsletter, November/December 2017.
- Social media/online content
 - Uploaded and shared over 50 videos recorded from our research (videos can be found at: <https://www.youtube.com/channel/UCwO28FdZ-UHZNvdWxR3nDNg>)
 - Shared several videos and photographs of research via the Voyageurs National Park and Voyageurs National Park Association Facebook pages.
- Manuscripts submitted or published in peer-reviewed science journals:
 - Gable, T.D., Windels, S.K., Romanski, M.C., and Rosell, F. *In Press*. The Forgotten Prey of an Iconic Predator: A Review of Gray Wolf-Beaver Dynamics. *Mammal Review*.
 - Gable, T.D. Stanger, T., Bump, J.K., and Windels, S.K. *In Review*. Do wolves ambush beavers? Video evidence of higher order strategies. *Ecosphere*.

Status as of June 30, 2018:

List of Dissemination/Outreach during reporting period:

- Public presentations:
 - Gable, T.D., S.K. Windels, and J.K. Bump. Do wolves ambush beavers from downwind hunting beds? Oral presentation, Minnesota Chapter of The Wildlife Society, St. Cloud, MN, Feb 2018.
 - Gable, T.D., S.K. Windels, and J.K. Bump. Do wolves ambush beavers from downwind hunting beds? Oral presentation, 78th Midwest Fisheries and Wildlife Conference, Milwaukee, WI, Jan 2018.

- J.K. Bump, T.D. Gable, J. Pruszenski, and S.K. Windels. Collaborative studies of wolf ecology in the Greater Voyageurs National Park Ecosystem. Oral presentation, 78th Midwest Fisheries and Wildlife Conference, Milwaukee, WI, Jan 2018.
- Social media/online content:
 - Uncovering the secret lives of wolves. Article in Quetico Superior Wilderness News <http://queticosuperior.org/blog/uncovering-the-secret-lives-of-wolves> and reprinted in Agate magazine <http://www.agatemag.com/2018/06/uncovering-the-secret-lives-of-wolves/>
 - Do wolves ambush beavers? Evidence shows wolves employ versatile hunting strategies. Article on University of Minnesota CFANS website. <https://www.cfans.umn.edu/wolves-hunting>
 - Several Facebook posts from National Park Service pages related to the project.
- Manuscripts submitted or published in peer-reviewed science journals:
 - Gable, T.D., S.K. Windels, F. Rosell, and M. Romanski. 2018. The forgotten prey of an iconic predator: a review of gray wolf-beaver dynamics. *Mammal Review* 48:123-138.
 - Gable, T.D., T. Stanger, J.K. Bump, and S.K. Windels. 2018. Do wolves ambush beavers? Video evidence for higher-order hunting strategies. *Ecosphere* 9(3):e02159. doi 10.1002/ecs2.2159
 - Gable, T.D., S.K. Windels, and J.K. Bump. *In Press*. Improving the efficacy of howl surveys: locating wolf homesites to study wolves during summer. *PeerJ*.

Status as of January 1, 2019:

List of Dissemination/Outreach during reporting period:

- Peer-reviewed scientific publications published, submitted, or in prep in 2018:
 - Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. *In Prep*. Draining the waterworks: how wolves halt ecosystem engineering by killing dispersing beavers. Targeted for *Nature Ecology & Evolution*.
 - Gable, T.D., A.T. Homkes, S.K. Windels, J.G. Bruggink, and J. K. Bump. *In Prep*. Kill two fawns with one wolf: the ability of wolves to find hidden prey. Target journal undecided.
 - Homkes, A.T., T.D. Gable, S.K. Windels, and J.K. Bump. *Submitted*. Wolf (*Canis lupus*) provisions pups with berries in northern Minnesota: evidence of the values of berries as a food source for wolves in southern boreal ecosystems? *Mammalian Biology*.
 - Gable, T.D., and S.K. Windels. *In Prep*. Proportion of cementum accurately predicts age: new method to estimate age of semi-aquatic mammal. Targeted for *Journal of Mammalogy*.
 - Gable, T.D., S.K. Windels and A. Homkes. *In Review*. Trumpeter swan killed by gray wolf in northern Minnesota. *Wilson's Journal of Ornithology*.
 - Gable, T.D., and D.P. Gable. *Accepted*. Gray wolf (*Canis lupus*) attacks life-like deer decoy: insight into how wolves hunt white-tailed deer? *Canadian Field Naturalist*.
 - Gable, T.D., S.K. Windels, and J.K. Bump. 2018. Finding wolf homesites: improving the efficacy of howl surveys to study wolves. *PeerJ* 6:e5629.
 - Gable, T.D., S.K. Windels and A. Homkes. 2018. Do wolves hunt fish in spring as food source? *Mammalian Biology* 91:30-33.
 - Gable, T.D., T. Stanger, S.K. Windels, and J.K. Bump. 2018. Do wolves ambush beavers? Video evidence for higher-order strategies. *Ecosphere*. 9:e02159.
 - Gable, T.D., S.K. Windels. M. Romanski, and F. Rosell. 2018. The forgotten prey of an iconic predator: a review of interactions between grey wolves *Canis lupus* and beavers *Castor* spp. *Mammal Review* 48: 123-138.
- Presentations at Regional, National, or International Conferences in 2018.

- Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. 2018. Wolf-beaver interactions: current insights and future directions. International Wolf Symposium, Minneapolis, Minnesota (Paper).
- Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. 2018. Where and how do wolves ambush beavers? International Wolf Symposium, Minneapolis, Minnesota.
- Homkes, A.T., S.K. Windels, J.G. Bruggink, T.D. Gable, and J.K. Bump. 2018. Where do wolves kill white-tailed deer fawns? International Wolf Symposium, Minneapolis, Minnesota (Paper).
- Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. 2018. Wolf-beaver interactions: current insights and future directions. International Beaver Symposium, Denmark (Paper).
- Homkes, A.T., S.K. Windels, J.G. Bruggink, T.D. Gable, and J.K. Bump. 2018. Where do wolves kill white-tailed deer fawns? Annual Meeting of the Minnesota Chapter of The Wildlife Society, St. Cloud, Minnesota (Paper).
- Homkes, A.T., S.K. Windels, J.G. Bruggink, T.D. Gable, and J.K. Bump. 2018. Where do wolves kill white-tailed deer fawns? 78th Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin (Paper).

Public Presentations

- Gable, T.D. 2018. Understanding the secret lives of wolves in the Greater Voyageurs Ecosystem. Voyageurs National Park Association Members Breakfast, Minneapolis, Minnesota.
- Gable, T.D. 2018. Understanding the secret lives of wolves in the Greater Voyageurs Ecosystem. Rainy Lake Conservancy Annual Meeting 2018, Fort Frances, Ontario.
- Gable, T.D. 2018. How do wolves hunt beavers? University of Minnesota-Twin Cities Spring 2018 Tuesday Seminar Series.
- Social media/online content:
 - Started Facebook page in November 2018 and as of December 16, 2018, over 1.4 million people on Facebook have seen results from our project that were posted on our page.
 - 2 Interviews for Media
 - i. Radio interview for 93.1. The Border in July 2018
 - ii. TV interview for PBS Minneapolis in December 2018
 - 46 news and popular articles about project in 2018
 - 3 popular articles written by project in 2018

Status as of June 30, 2019:

List of Dissemination/Outreach during reporting period:

- Peer-reviewed scientific publications published or submitted
 - Homkes, A.T., T.D. Gable, S.K. Windels, and J.K. Bump. *Submitted*. Wolf (*Canis lupus*) provisions pups with berries in northern Minnesota: evidence of the values of berries as a food source for wolves in southern boreal ecosystems? *Wildlife Society Bulletin*.
 - Gable, T.D., S.K. Windels, A. Homkes, G. Robertson, and E.K. Verveniotis. 2019. Trumpeter swan killed by gray wolf in northern Minnesota. *Northeastern Naturalist* 26: 27-30.
 - Gable, T.D., and D.P. Gable. *Accepted*. Gray wolf (*Canis lupus*) attacks life-like deer decoy: insight into how wolves hunt white-tailed deer? *Canadian Field Naturalist*.
- Peer-reviewed scientific publications in prep
 - Gable, T.D., A.T. Homkes, S.K. Windels, and J. K. Bump. *In Prep*. Chance encounter or biological phenomenon? Two dispersing wolves interact after dispersing >300 kilometers from the Greater Voyageurs Ecosystem, Minnesota. Target journal *Canadian Wildlife Biology and Management*.

- Gable, T.D., A.T. Homkes, S.K. Windels, and J. K. Bump. *In Prep.* Wolves use olfactory concealment and strategic positioning to ambush beavers. Target journal undecided.
- Gable, T.D., S.K. Windels, A.T. Homkes, S.M. Johnson-Bice, and J. K. Bump. *In Prep.* Draining the waterworks: how wolves halt ecosystem engineering by beavers. Target journal Nature Ecology and Evolution.
- Gable, T.D., A.T. Homkes, S.K. Windels, J.G. Bruggink, and J. K. Bump. *In Prep.* Kill two fawns with one wolf: the ability of wolves to find hidden prey. Target journal undecided.
- Presentations at Regional, National, or International Conferences.
 - Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. 2019. The Voyageurs Wolf Project: uncovering the secret lives of wolves. Heart of the Continent Symposium, Duluth, Minnesota.
 - Gable, T.D., S.K. Windels, A.T. Homkes, S. Johnson-Bice, and J.K. Bump. 2019. Draining the waterworks: how wolves halt ecosystem engineering by dispersing beavers. Annual Meeting of the Minnesota Chapter of The Wildlife Society, Duluth, Minnesota (Paper).
 - Windels, S.K. 2019. Challenges and opportunities for managing wolves in protected areas: a case study from Minnesota, USA. The Wolf in Europe Symposium, Halberstadt, Germany (Invited Paper).
- Public Presentations
 - Gable, T.D. 2019. Voyageur Wolf Project: the secret lives of wolves. 2019 Teen Ambassadors from Voyageurs National Park Association, Ash River, MN.
 - Bump, J.K. 2019. The Voyageurs Wolf Project. Invited presentation at Bell Museum. Saint Paul, MN.
 - Bump, J.K. 2019. Humans, Wolves, and the Voyageurs Wolf Project. Invited seminar for American Association of University Women. Saint Paul, MN
 - Bump, J.K. 2019. Voyageurs Wolf Project: summertime wolf ecology in the Northwoods. 2019 Spring Seminar Series, Carleton College, Minnesota.
 - Gable, T.D. 2019. The wolves of the Greater Voyageurs Ecosystem. International Wolf Center Webinar, Minnesota.
- Social media/online content:
 - Created and maintained Facebook Page, Instagram Account, and Youtube Channel
 - Reached >3.7 million people via project Facebook page since November 2018 and are gaining an average of 44 project page followers per day (total Facebook following: 17,796 followers)
 - Multiple public presentations and radio/TV interviews
 - Project featured 3 national television shows (PBS Nature, Right This Minute, and Rock the Park)

Status as of January 1, 2020:

List of Dissemination/Outreach during reporting period:

- Peer-reviewed scientific publications published or submitted
 - Homkes, A.T., T.D. Gable, S.K. Windels, and J.K. Bump. 2019. Wolf (*Canis lupus*) provisions pups with berries in northern Minnesota: evidence of the values of berries as a food source for wolves in southern boreal ecosystems? *Wildlife Society Bulletin*.
 - Gable, T.D., and D.P. Gable. 2019. Gray wolf (*Canis lupus*) attacks life-like deer decoy: insight into how wolves hunt white-tailed deer? *Canadian Field Naturalist*.
- Presentations at Regional, National, or International Conferences.
- Public Presentations
- Media Outreach
 - "Video captures wolves in northern Minnesota eating blueberries" in Duluth News Tribune. February 2020

- "Wolves regurgitate blueberries for their pups to eat" in Science News. February 2020
- Finding Fur and Feathers interviewed Joe Bump for their episode "What happens with wolves now?" in October 2020
- "Following a lone wolf, all the way from Minnesota to Lake Nipigon" on CBC's Up North program in September 2020
- Social media/online content:
 - Created and maintained Facebook Page, Instagram Account, Youtube Channel, and Twitter account

Status as of June 29, 2020:

List of Dissemination/Outreach during reporting period:

- Peer-reviewed scientific publications published or submitted
 - Homkes, A.T., T.D. Gable, S.K. Windels, and J.K. Bump. 2020. Berry important? Wolf provisions pups with berries in northern Minnesota. *Wildlife Society Bulletin* 44(1): 221-223.
 - Gable, T.D., A.T. Homkes, S.M. Johnson-Bice, S.K. Windels, and J.K. Bump. *Submitted*. Wolves choose ambushing locations based on the sensory defenses and deficiencies of their prey. *Behavioral Ecology*.
 - Gable, T.D., A.T. Homkes, S.K. Windels, and J.K. Bump. *Submitted*. Wolves use cooperative ambush strategies to hunt beavers.
- Presentations at Regional, National, or International Conferences.
- Public Presentations
- Media Outreach
 - "Video captures wolves in northern Minnesota eating blueberries" in Duluth News Tribune. February 2020
 - "Wolves regurgitate blueberries for their pups to eat" in Science News. February 2020.
- Social media/online content:
 - Created and maintained Facebook Page, Instagram Account, Youtube Channel, and Twitter account

Status as of January 1, 2021:

List of Dissemination/Outreach during reporting period:

- Peer-reviewed scientific publications published or submitted
 - Gable, T.D., S.M. Johnson-Bice, A.T. Homkes, S.K. Windels, and J.K. Bump. 2020. Outsized effect of predation: wolves alter wetland creation and recolonization by killing ecosystem engineers. *Science Advances*.
 - Gable, T.D., A.T. Homkes, S.M. Johnson-Bice, S.K. Windels, and J.K. Bump. *Submitted*. Wolves choose ambushing locations based on the sensory defenses and deficiencies of their prey. *Behavioral Ecology*.
 - Gable, T.D., A.T. Homkes, S.K. Windels, and J.K. Bump. *Submitted*. Wolves use cooperative ambush strategies to hunt beavers.
- Presentations at Regional, National, or International Conferences
- Public Presentations
- Media Outreach

- "Wolf attacks on beavers are altering the very landscape of a national park" in Science. November 2020
- "Wolves preying on beavers in Minnesota reshape wetlands" in The Associated Press. November 2020
- "Wolves shape ecosystems by preying on beavers" in IFLScience. November 2020.
- "Scientists discover a completely unexpected way wolves alter ecosystems" in Inverse. November 2020.
- "Wolf researchers in Voyageurs National Park believe unlikely food source may be behind moose success" in Minneapolis Star Tribune. August 2020
- Social media/online content:
 - Created and maintained Facebook Page, Instagram Account, Youtube Channel, and Twitter account

Final Report Summary:

The following outreach was conducted as part of the research funded by this current LCCMR grant, during the period Sept 2017-March 2021. While the lists of publications and presentations are complete, the accounting of media attention garnered is likely incomplete due to the number of stories written and reprinted elsewhere. Likewise, the social media section is not an accounting of individual account activity but an overall account of the social media influence, which is considerable. The University of Minnesota's Voyageurs Wolf Project, in particular, was very successful at creating public interest in the project through social media and other media interest.

Twelve (12) manuscripts in peer-reviewed science journals (published or submitted). PDFs of published manuscripts included in Supplementary Materials:

1. Gable, T. D., and S. K. Windels. 2018. Kill rates and predation rates of wolves on beavers. *Journal of Wildlife Management* 82:466–472.
2. Gable, T.D., T. Stanger, J.K. Bump, and S.K. Windels. 2018. Do wolves ambush beavers? Video evidence for higher-order hunting strategies. *Ecosphere* 9 (3):e02159. doi 10.1002/ecs2.2159
3. Gable, T.D., S.K. Windels, and J.K. Bump. 2018. Finding wolf homesites: improving the efficacy of howl surveys to study wolves. *PeerJ* 6:e5629.
4. Gable, T.D., S.K. Windels, and A. Homkes. 2018. Do wolves hunt fish in spring as food source? *Mammalian Biology* 91:30-33.
5. Gable, T. D., S. K. Windels, and I. C. Rautio. 2018. River Otter (*Lontra canadensis*) Killed by Wolves (*Canis lupus*) during Winter in Northern Minnesota. *Canadian Field-Naturalist* 131:252–253.
6. Gable, T.D., S.K. Windels, F. Rosell, and M. Romanski. 2018. The forgotten prey of an iconic predator: a review of gray wolf-beaver dynamics. *Mammal Review* 48:123-138.
7. Gable, T. D., A. T. Homkes, S. K. Windels, and J. K. Bump. 2019. Is there a mechanism that causes wolves from same area to disperse long-distances in same direction? *Canadian Wildlife Biology & Management* 8:62-65.
8. Gable, T.D., S.K. Windels, A. Homkes, G. Robertson, and E.K. Verveniotis. 2019. Trumpeter swan killed by gray wolf in northern Minnesota. *Northeastern Naturalist* 26: 27-30.

9. Gable, T. D., S. M. Johnson-Bice, A. T. Homkes, S. K. Windels, and J. K. Bump. 2020. Outsized effect of predation: wolves alter wetland creation and recolonization by killing ecosystem engineers. *Science Advances* 6: eabc5439.
10. Homkes, A.T., T.D. Gable, S.K. Windels, and J.K. Bump. 2020. Berry important? Wolf provisions pups with berries in northern Minnesota. *Wildlife Society Bulletin* 44(1): 221-223.
11. Gable, T. D., A. T. Homkes, S.M. Johnson-Bice, S. K. Windels, and J. K. Bump. 2021. Wolves choose ambushing locations to counter and capitalize on the sensory abilities of their prey. *Behavioral Ecology* XX(XX).
12. Gable, T.D., A.T. Homkes, S.K. Windels, and J.K. Bump. *Submitted*. Wolves use cooperative ambush strategies to hunt beavers. *Ethology*.

Three (3) reports/dissertations/theses:

1. Gable, T.D. 2020. Wolf-Beaver Dynamics in a Southern Boreal Ecosystem. Ph.D. Dissertation, University of Minnesota, St. Paul, MN.
2. Homkes, A.T. 2020. Wolf Selection of Human-Modified Linear Features and Cover Types When Hunting and Killing White-Tailed Deer Fawns. M.S. Thesis, Northern Michigan University, Marquette, MI.
3. Gable, T.D., A.T. Homkes, and J.K. Bump. 2021. 2020-2021 Greater Voyageurs Ecosystem Wolf Pack and Population Size Report. University of Minnesota.

Thirteen (13) presentations at scientific conferences or symposia:

1. Bump, J.K, T.D. Gable, J. Pruszenski, and S.K. Windels. Collaborative studies of wolf ecology in the Greater Voyageurs National Park Ecosystem. Oral presentation, 78th Midwest Fisheries and Wildlife Conference, Milwaukee, WI, Jan. 2018.
2. Gable, T.D., S.K. Windels, and J.K. Bump. Do wolves ambush beavers from downwind hunting beds? Oral presentation, 78th Midwest Fisheries and Wildlife Conference, Milwaukee, WI, Jan. 2018.
3. Homkes, A.T., S.K. Windels, J.G. Bruggink, T.D. Gable, and J.K. Bump. 2018. Where do wolves kill white-tailed deer fawns? Oral presentation, 78th Midwest Fisheries and Wildlife Conference, Milwaukee, WI, Jan. 2018.
4. Gable, T.D., S.K. Windels, and J.K. Bump. Do wolves ambush beavers from downwind hunting beds? Oral presentation, Minnesota Chapter of The Wildlife Society, St. Cloud, MN, Feb. 2018.
5. Homkes, A.T., S.K. Windels, J.G. Bruggink, T.D. Gable, and J.K. Bump. Where do wolves kill white-tailed deer fawns? Oral presentation, Annual Meeting of the Minnesota Chapter of The Wildlife Society, St. Cloud, Minnesotam, Feb. 2018.
6. Windels, S.K. et al. Patterns of wolf predation on ungulate neonates in Minnesota. Oral presentation, 52nd North American Moose Conference and Workshop, Spokane, WA, May 2018.
7. Gable, T.D., S.K. Windels (presenter), A.T. Homkes, and J.K. Bump. Wolf-beaver interactions: current insights and future directions. Oral presentation, International Beaver Symposium, Denmark, Sept. 2018.
8. Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. Wolf-beaver interactions: current insights and future directions. Oral presentation, International Wolf Symposium, Minneapolis, Minnesota, Oct. 2018.
9. Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. Where and how do wolves ambush beavers? Oral presentation, International Wolf Symposium, Minneapolis, Minnesota, Oct. 2018.

10. Homkes, A.T., S.K. Windels, J.G. Bruggink, T.D. Gable, and J.K. Bump. Where do wolves kill white-tailed deer fawns? Oral presentation, International Wolf Symposium, Minneapolis, Minnesota, Oct. 2018.
11. Gable, T.D., S.K. Windels, A.T. Homkes, and J.K. Bump. The Voyageurs Wolf Project: uncovering the secret lives of wolves. Oral presentation, Heart of the Continent Symposium, Duluth, Minnesota, Apr. 2019.
12. Windels, S.K. Challenges and opportunities for managing wolves in protected areas: a case study from Minnesota, USA. Invited keynote address, The Wolf in Europe Symposium, Halberstadt, Germany, Apr. 2019.
13. Gable, T.D., S.K. Windels, A.T. Homkes, S. Johnson-Bice, and J.K. Bump. Draining the waterworks: how wolves halt ecosystem engineering by dispersing beavers. Oral presentation, Annual Meeting of the Minnesota Chapter of The Wildlife Society, Duluth, Minnesota, Feb. 2019.

≥Thirteen (13) presentations at public events (not a complete list):

1. Gable, T.D. Pints for the Park, Voyageurs National Park Association, November 16, 2017.
2. Gable T.D. How do wolves hunt beavers? Presentation/talk for International Wolf Center volunteer appreciation dinner, December 14, 2017.
3. Gable, T.D. Understanding the secret lives of wolves in the Greater Voyageurs Ecosystem. Voyageurs National Park Association Members Breakfast, Minneapolis, Minnesota, 2018.
4. Gable, T.D. Understanding the secret lives of wolves in the Greater Voyageurs Ecosystem. Rainy Lake Conservancy Annual Meeting 2018, Fort Frances, Ontario.
5. Windels, S.K. Six degrees of beaver ecology: collaborations on an ecosystem engineer. Departmental Seminar Series, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, Minnesota, Nov 2018.
6. Gable, T.D. How do wolves hunt beavers? University of Minnesota-Twin Cities Spring 2018 Tuesday Seminar Series.
7. Gable, T.D. Voyageur Wolf Project: the secret lives of wolves. Teen Ambassadors, Voyageurs National Park Association, Ash River, MN, 2019.
8. Bump, J.K. The Voyageurs Wolf Project. Invited presentation at Bell Museum. Saint Paul, MN, 2019
9. Bump, J.K. Humans, Wolves, and the Voyageurs Wolf Project. Invited seminar for American Association of University Women. Saint Paul, MN, 2019.
10. Bump, J.K. Voyageurs Wolf Project: summertime wolf ecology in the Northwoods. 2019 Spring Seminar Series, Carleton College, Minnesota.
11. Gable, T.D. The wolves of the Greater Voyageurs Ecosystem. International Wolf Center Webinar, Minnesota, 2019.
12. Windels, S.K. Thinking Like a Pond: Beavers and Watershed Management in the Western Great Lakes. UMN Sustainable Forests Education Cooperative 2020 Webinar Series. January 21, 2020.
13. Windels, S.K. Summary of moose monitoring and research in Voyageurs National Park. Minnesota Moose Research and Management Meeting, July 2021.

Print/Other media (not be a complete list):

- “What is a rendezvous site?” by Tom Gable. Wolf Park Newsletter, November/December 2017.

- "Uncovering the secret lives of wolves." Article in Quetico Superior Wilderness News <http://queticosuperior.org/blog/uncovering-the-secret-lives-of-wolves> and reprinted in Agate magazine <http://www.agatemag.com/2018/06/uncovering-the-secret-lives-of-wolves/>. March 2018.
- "An elusive wolf—and the months spent tracking him" by Tom Gable for International Wolf Magazine; Spring 2018
- Radio interview for 93.1. The Border, July 2018
- TV interview for PBS Minneapolis, December 2018
- "Do wolves ambush beavers? Evidence shows wolves employ versatile hunting strategies." Article on University of Minnesota CFANS website.
- "Reframing the predation behavior of a charismatic carnivore: how do wolves hunt beavers?" by Tom Gable for Quetico-Superior Wilderness News; Spring 2019
- "America's best idea at work: 45 years of wolf science and conservation in Voyageurs National Park" by Steve Windels for PBS Nature Blog; Spring 2019
- "Are wolves ambush predators? How wolves hunt beavers" by Tom Gable for Winter Wolf Park Newsletter; Winter 2019
- "Video captures wolves in northern Minnesota eating blueberries" in Duluth News Tribune. February 2020
- "Wolves regurgitate blueberries for their pups to eat" in Science News. February 2020
- Finding Fur and Feathers interviewed Joe Bump for their episode "What happens with wolves now?" in October 2020
- "Following a lone wolf, all the way from Minnesota to Lake Nipigon" on CBC's Up North program in September 2020
- "Video captures wolves in northern Minnesota eating blueberries" in Duluth News Tribune. February 2020
- "Wolves regurgitate blueberries for their pups to eat" in Science News. February 2020.
- People and Wolves Talk Show, April 2020.
- "Wolf attacks on beavers are altering the very landscape of a national park" in Science. November 2020
- "Wolves preying on beavers in Minnesota reshape wetlands" in The Associated Press. November 2020
- "Wolves shape ecosystems by preying on beavers" in IFLScience. November 2020.
- "Scientists discover a completely unexpected way wolves alter ecosystems" in Inverse. November 2020.
- "Wolf researchers in Voyageurs National Park believe unlikely food source may be behind moose success" in Minneapolis Star Tribune. August 2020
- "How the Wolves Change the Forest". Scientific American podcast, Dec. 2020. <https://www.scientificamerican.com/podcast/episode/how-the-wolves-change-the-forest/>
- Project featured 3 national television shows (PBS Nature, Right This Minute, and Rock the Park).

Social media/online content

- University of Minnesota created and maintained Voyageurs Wolf Project Facebook page, Instagram account, Twitter account, and YouTube Channel, all very successful social media accounts:
 - i. Facebook page, started in November 2018, has almost 150,000 followers as of Nov. 2021.
 - ii. Instagram account has >25,000 followers as of Nov. 2021.
 - iii. Twitter account has >18,000 followers as of Nov. 2021.
 - iv. Uploaded and shared over 50 videos recorded from our research (videos can be found at: <https://www.youtube.com/channel/UCwO28FdZ-UHZNvdWxR3nDNg>)
- Shared several videos and photographs of research via the Voyageurs National Park and Voyageurs National Park Association Facebook pages.
- Multiple Facebook posts from National Park Service pages related to the project.

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:	\$ 156,500	NATIONAL PARK SERVICE: 4 interns at 20% FTE for 2 years = \$6,500. UNIVERSITY OF MINNESOTA-TWIN-CITIES: 1 graduate research assistant at 50% FTE for 2.75 years (\$120,000); 2 undergraduate research assistants at 33% FTE for 2 years (\$30,000). Allocation of effort among personnel categories are estimates that may be adjusted to best meet project objectives.
Professional/Technical/Service Contracts:	\$72,000	NATIONAL PARK SERVICE: GPS collar data acquisition for 3 years. \$2000/collar/yr for 3 years * 12 collars/yr.
Equipment/Tools/Supplies:	\$41,500	NATIONAL PARK SERVICE: 24 GPS collars @\$1,500 ea = \$36,000; pharmaceuticals for wildlife capture = \$3,000; GPS units and other field supplies = \$2,500.
Travel Expenses in MN:	\$8,000	NATIONAL PARK SERVICE: Vehicle mileage = \$5000; boat gas for boat travel in park = \$3,000
Other:	\$15,000	NATIONAL PARK SERVICE: Flight time for beaver surveys; \$100/hr * 50 hours/yr * 3 years.
TOTAL ENRTF BUDGET:	\$293,000	

Explanation of Use of Classified Staff: N/A

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

Total Number of Full-time Equivalent (FTE) Directly Funded with this ENRTF Appropriation: 4.3 FTE

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

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
Voyageurs National Park (in-kind)	\$176,000	>\$400,000	Project management; supplemental wolf monitoring and kill sites visits; misc field supplies and equipment; boat and vehicle use; housing for interns; pilot salary; outreach
TOTAL OTHER FUNDS:	\$176,000	>\$400,000	

VII. PROJECT STRATEGY:

A. Project Partners:

Partners receiving ENRTF funding

- *Steve K. Windels; Wildlife Biologist; Voyageurs National Park; will supervise field component of the project; will co-advise PhD student at UMN and assist with aspects of study design, data analysis, and preparation of peer-reviewed manuscripts. Windels has 14 years of experience at Voyageurs National Park conducting applied research on wolves, beavers, moose, deer, and other wildlife.*
- *Joseph K. Bump; Associate Professor; Gullion Chair; University of Minnesota-Twin Cities; will co-advise PhD student at UMN and assist with aspects of study design, data analysis, and preparation of peer-reviewed manuscripts. Bump has 14-years of experience working on wildlife projects related to wolves and is in a position to support this project as a featured part of a newly established research lab at University of Minnesota-Twin Cities. This will increase the profile of this project, increase dissemination potential, and create new opportunities for funding, collaboration, synergetic research with other faculty in the Department of Fisheries, Wildlife, and Conservation Science.*

B. Project Impact and Long-term Strategy: If clear linkages can be found between beaver abundance and wolf predation rates on moose and deer, *potential management options exist where beaver populations could be manipulated to alleviate predation on moose and deer.* Options include reduced beaver harvest or incentives to encourage beavers in low density areas. This project would also contribute to continued understanding of the ecology of wolves and their prey in a natural setting in northern Minnesota.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	\$ Amount
Voyageurs National Park (in-kind): funding provided to conduct annual wolf monitoring, annual beaver monitoring, and diet analysis for several wolf packs.	October 2012-June 2017	>\$200,000

VIII. REPORTING REQUIREMENTS:

- **The project is for 43 years, will begin on 06/30/17, and end on 06/30/2021.**

- **Periodic project status update reports will be submitted [January 1] and [June 30] of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2021.**

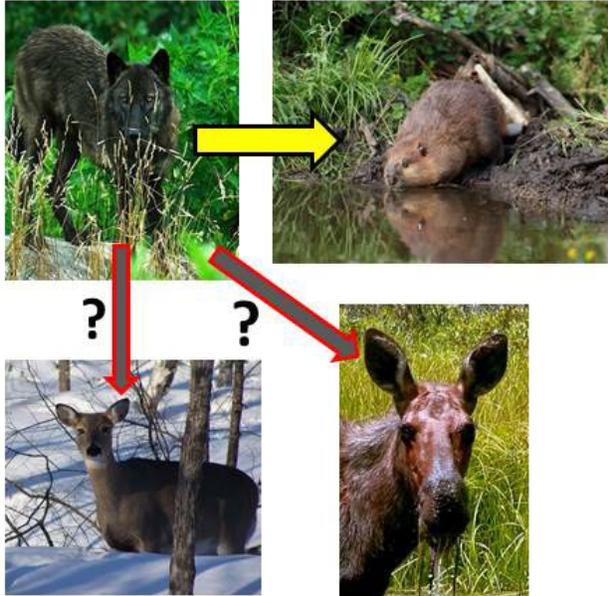
IX. VISUAL COMPONENT or MAP(S): see attached figures.

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A

Effects of Wolves on Beavers, Moose and Deer in Border Lakes Region

Wolves prey on moose, deer, and beavers. Does the availability of beavers, an easy food source, reduce predation pressure on moose and deer?



GPS collars on wolves can point to **locations** where wolves have killed prey. Species, sex, and age of prey items can be identified to understand wolf predation under high and low beaver densities.



Examples of wolf kill sites



Wolf-Killed Beaver



Wolf-Killed Moose

Fig. 1. Voyageurs National Park, Minnesota's only National Park, has prohibited trapping since establishment in 1975. This has resulted in a beaver-rich environment where beaver abundance is 2-10x higher than other parts of the state.

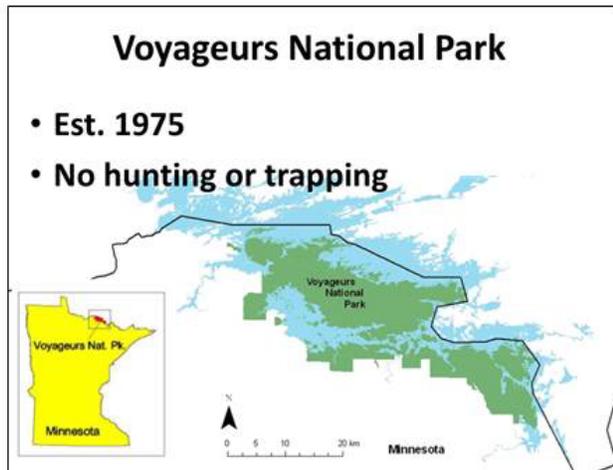
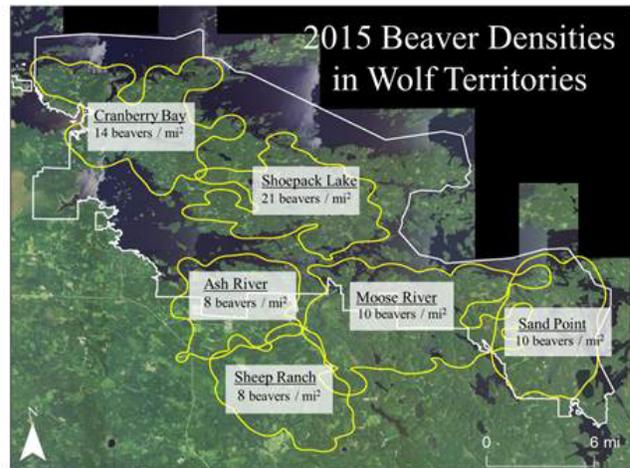


Fig. 2. Beaver abundance varies spatially in the Voyageurs National Park landscape due to differences in topography. This variability will allow us to test wolf hunting behavior in 6-8 packs that have varying abundances of beavers.



Project Synergy

This proposal builds on other current research and monitoring in Voyageurs National Park, allowing us to cost-effectively study the relationship between wolves, beavers, moose, and deer in a relatively natural system:

- 1959-present: Long-term beaver population monitoring
- 2006-present: Beaver research
- 2009-present: Moose and deer population monitoring and research
- 2012-present: Wolf population monitoring and research

Potential Outcomes of Proposed Project

- Potential management recommendations to manipulate beaver populations to alleviate predation on moose and deer. Options include reduced beaver harvest or incentives to encourage beavers in low density areas
- Inform recommendations of Moose Management Options Committee and/or Moose Advisory Committee
- Improve understanding of ecology of wolves and their prey in northern Minnesota

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

Project Title: Effects of Wolf Predation on Beaver, Moose, and Deer

Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 03I

Project Manager: Steve K. Windels

Organization: Voyageurs National Park

M.L. 2017 ENRTF Appropriation: \$293,000

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

Date of Report: Novemeber 14, 2021



ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Revised Budget (06/30/2019)	Amount Spent	Activity 1 Balance	Activity 2 Revised Budget (06/30/2019)	Amount Spent	Activity 2 Balance	Activity 3 Revised Budget (06/30/2019)	Amount Spent	Activity 3 Balance	TOTAL REVISED BUDGET (06/30/2019)	TOTAL BALANCE
BUDGET ITEM	<i>Determine Predation Rates...</i>			<i>Census Beaver Populations...</i>			<i>Evaluate Relationship....</i>				
Personnel (Wages and Benefits) - Overall											
4 Wildlife Interns (100% stipend @ \$200/mo), NPS; 20% FTE for 2 yrs; to assist with wolf capture and kill site visitation.	\$6,500	\$6,493	\$7			\$0			\$0	\$6,500	\$7
Professional/Technical/Service Contracts											
GPS-satellite collar data acquisition contract; 12 collars/yr for 3 years; ~\$600/yr/collar. To be selected through competitive bid.	\$22,250	\$22,250	\$0			\$0			\$0	\$22,250	\$0
University of Minnesota:											
Thomas Gable, Graduate Research Asst (56% salary, 44% benefits), UMN; 50% FTE for 3.25 yrs; will lead/coordinate all field work, data collection, analysis, writing, and public outreach = \$138,183 2 Undergraduate Research Technicians (100% salary, 0% benefits), UMN; 33% FTE for 2 yrs; for wolf capture and kill site visitation = \$30,000 Supplies = \$18,000 Travel = \$3,930 Other = \$9,637	\$171,453	\$171,453	\$0	\$9,432	\$9,432	\$0	\$18,865	\$16,515	\$2,350	\$199,750	\$2,350
Equipment/Tools/Supplies											
GPS-satellite wolf collars; \$1500/collar for 24 collars to maintain 2 collars/pack for 3 years. Includes replacements for lost/damaged collars. To be selected through competitive bid.	\$36,000	\$36,000	\$0			\$0			\$0	\$36,000	\$0
Pharmaceuticals for wolf capture @ \$83/capture * 36 captures	\$3,000	\$576	\$2,424			\$0			\$0	\$3,000	\$2,424
Misc field supplies for scat collection, stable isotopes, kill site visitation. E.g., GPS units, sample bags, field notebooks, etc.	\$2,500	\$2,449	\$51			\$0			\$0	\$2,500	\$51
Travel expenses in Minnesota											
Mileage paid to GSA per Federal guidelines. Boat gas for NPS-owned boats.	\$8,000	\$8,000	\$0			\$0			\$0	\$8,000	\$0
Other											
Flight time for annual beaver census (\$100/hr) 50 hours/yr for Year 1-3. Rate for NPS-owned aircraft per Federal govt. guidelines.			\$0	\$15,000	\$15,000	\$0			\$0	\$15,000	\$0
COLUMN TOTAL	\$249,703	\$247,221	\$2,482	\$24,432	\$24,432	\$0	\$18,865	\$16,515	\$2,350	\$293,000	\$4,832

Effects of Wolves on Beavers, Moose and Deer in Border Lakes Region

Wolves prey on moose, deer, and beavers. Does the availability of beavers, an easy food source, reduce predation pressure on moose and deer?



? ?



GPS collars on wolves can point to **locations** where wolves have killed prey. Species, sex, and age of prey items can be identified to understand wolf predation under high and low beaver densities.



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Wolf-Killed Moose

