2019 Project Abstract
For the Period Ending June 30, [2023]

PROJECT TITLE: Spruce Grouse as Indicators for Boreal Forest Connectivity

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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 03e
APPROPRIATION AMOUNT: $350,000
AMOUNT SPENT: $344,910
AMOUNT REMAINING: $5,090

Sound bite of Project Outcomes and Results

We suggest that forest management to promote dense understory structure in boreal forest may provide climate refugia for various species of early successional forest wildlife. The landscape context should also be considered in forest planning in a changing climate to ensure that landscape connectivity is managed to meet wildlife needs.

Overall Project Outcome and Results

We completed a 4-year study (2019-2022) to examine spruce grouse (*Canachites canadensis*) occupancy of conifer forest patches, responses to timber harvest, and genetic connectivity in the boreal forest of northern Minnesota. We conducted a pellet survey of forest stands during late winter/early spring and documented the presence/absence of spruce grouse and other forest wildlife species, as it related to various landscape and forest attributes and climate variables. We examined changes in spruce grouse survival and space use in response to timber harvest with radio-marked birds. We also collected feathers from hunters and during capture efforts to examine landscape connectivity for spruce grouse using genetic methods. Our occupancy results indicated that forest management practices that promote dense vegetation structure may benefit spruce grouse, especially a dense mid-canopy layer (5.0 – 15.0 m). The mid-canopy layer was not as important for the other wildlife species we examined. Our telemetry data indicated that spruce grouse have lower survival after timber harvest, but that most harvested conifer stands were avoided prior to harvest, likely due to the sparse midstory vegetation structure in many of these mature stands. We suggest that reduced spruce grouse survival after timber harvest may be due to indirect effects of timber harvest, such as harvest-related changes in predator behavior or predator space use (e.g., edge effects, changes in predator density in nearby stands) rather than habitat loss. Finally, our genetic data indicated that spruce grouse exist as a single interconnected population in Minnesota, with coniferous forest land cover and lower average temperatures during spring dispersal being the best predictors of gene flow. Therefore, climate change could potentially threaten the persistence of the single interconnected population.

Project Results Use and Dissemination

We gave a field presentation to DNR Region 2 Assistant Wildlife Managers (August). We will present for 1) the Northeast Regional Landscape Minnesota Forest Resources Council (October), 2) The Wildlife Society Annual Meeting in November, 3) a DNR hosted Wildife Research Webinar (December), 4) the Midwest Fish and Wildlife Conference (January), and 5) at the Minnesota Chapter of The Wildlife Society (February). A freelance reporter is writing a story on the study for release winter 2023. We submitted a manuscript on Activity 1 to *Forest Ecology and Management*. At least 2 more manuscripts will be submitted to scientific journals soon.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2019 ENRTF Work Plan (Main Document)

Today's Date: 31 July 2023

Date of Next Status Update Report: Final Report

Date of Work Plan Approval: 5 June 2019

Project Completion Date: 30 June 2023

Does this submission include an amendment request? No

PROJECT TITLE: Spruce Grouse as Indicators for Boreal Forest Connectivity

Project Manager: Julia B Ponder, DVM, MPH

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Location: Northeast and Northwest

Total Project Budget: $350,000

Amount Spent: $344,910

Balance: $5.090

Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 03e

Appropriation Language: $350,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Raptor Center to evaluate how to best harvest timber in the boreal forest to enable wildlife with small home ranges, such as spruce grouse, to thrive in a changing landscape. This appropriation is available until June 30, 2023, by which time the project must be completed and final products delivered.

I. PROJECT STATEMENT: Our primary objective is to study how the composition, arrangement, and size of boreal forest stands influence wildlife use of forest stands to allow incorporation of wildlife needs in forest planning. Five scientific models predict that the spruce-fir forest will shift entirely north of the US border with warmer summers and drought. As these shifts occur, maintaining habitat patches close enough to each other to allow wildlife to move successfully between patches will be important to:

- Maintain sustainable populations
- Allow colonization of new areas in a changing landscape

The recently completed Sustainable Timber Harvest Analysis conducted under Governor Dayton's direction will result in the harvest of 870,000 cords with 30,000 additional cords of ash and tamarack on lands managed by the Department of Natural Resources for the next 10 years. Our study will provide data on how close forest patches of similar composition should be to each other to accommodate even the most short-ranging wildlife.

Spruce grouse prefer black spruce, jack pine, and tamarack stands with pilot data from Northwest Minnesota indicating that they use <200 acres year round, although they are capable of moving farther. Thus, spruce grouse are short-ranging. Species most likely to be adversely impacted by landscape fragmentation and habitat loss are those with limited movement capabilities or tendencies to make short movements, and those with very specific habitat requirements. Thus, spruce grouse may serve as a sentinel of connectivity deficiencies among stands and creation of forest islands. We propose to use spruce grouse as a sentinel species for other boreal species at both local and landscape scales.

Good sentinels are easy to survey and are common, so a lot of data can be collected easily. The first annual spruce grouse survey was launched in 2018 and provides a pellet survey methodology and large scale data set on spruce grouse occupancy of forest stands. Additionally, good sentinels for forest connectivity should also be sensitive to factors that impact forest connectivity, such as timber harvest, and should have high overlap with harvested stands.

- We will conduct pellet surveys to relate spruce grouse occupancy of forest stands to site- and landscape-level characteristics.
- We will examine factors like mean patch size, stand type, patch density, and mean distance to nearest conifer patch to understand their influence on forest connectivity for spruce grouse in a Minnesota landscape.
- We will examine spruce grouse responses to timber harvest by marking spruce grouse with radio-transmitters to monitor movements and survival before and after timber harvest. We will determine whether responses to timber harvest in winter differ from responses in summer.
- Finally, to identify existing forest connectivity issues, we will collect spruce grouse fecal pellets from across northern Minnesota to obtain genetic samples. We will relate landscape features to genetic isolation and connectivity.

II. OVERALL PROJECT STATUS UPDATES:

First Update March 1, 2020

We have initiated work on all 3 activities, including hiring 2 seasonal technicians to work on Activity 1, hiring 2 seasonal technicians to work on activity 2, and sending a first round of spruce grouse pellet and feather samples to University of Minnesota Genomics Center for genetic analysis for Activity 3.

Second Update September 1, 2020

Progress on the project was heavily impacted by the COVID-19 pandemic. Governor Walz's Executive Order (EO) 20-20 and 20-33 directed state employees to stay home except to perform essential work during 28 March – 4 May 2020. This halted fieldwork by five project staff, including two seasonal technicians working on Activities 1 and 3, two temporary technicians working on Activity 2, and the Principal Investigator (PI) leading field studies on all three activities at DNR. The Governor exempted fieldwork for research and surveys on 4 May in EO 20-48, but the DNR Commissioner wanted to ensure the safe return of staff to the field and thus a gradual return to field activities was implemented. One seasonal technician was authorized to return to the field on 8 May. On 27 May, the PI and another seasonal technician were authorized to resume fieldwork. The two seasonal technicians working on Activities 1 and 3 were no longer in employment with the DNR when fieldwork resumed because their two month appointments ended during the Stay-at-Home Order (April 30), and thus they did not resume fieldwork.

The timing of the Stay-at-Home Order overlapped with critical periods for all three activities. Pellet surveys for Activities 1 and 3, which were planned to occur March – April, were truncated by 50%, with only surveys in the western portion of the survey area completed before EO 20-20 went into effect. The eastern portion of the survey area generally has higher spruce grouse densities, so we expected the majority of our genetic samples to come from the eastern region, which could not be surveyed in April as planned. Similarly, spring capture efforts to meet objectives in Activity 2 were halted (April–mid May) at the beginning of the capture season when we expected to mark the majority of the birds for the study. We also could not radio-track the 18 birds that had already been marked.

We did not budget for a spring 2021 field season on Activities 1 and 3 and had planned for spring 2020 to be our final field season. For Activity 2, we did budget for spring 2021 field season, but it was supposed to be markedly smaller than the spring 2020 field season. Later capture and marking will necessitate later radio-tracking of a newly marked birds. The missed season did not come with a saving in expenditures because we had already hired technicians. With the current budget, we have several options. We can reduce Activity 2, to pay for another field season on Activities 1 and 3, and complete those activities with a 1-year delay. This hinges on being able to hire field technicians to begin work in Mar 2021. With the current funding, we would exhaust the current funds in Oct 2021 for fieldwork on Activity 2. This would allow for only 6 months of radio-tracking of birds marked in spring 2021, which is 25-50% of the expected radio-life, and also would not include the winter 2021-2022 timber harvest season. If we had additional funds to cover Activities 1 and 3, we could continue radio-tracking birds into December 2021. Two more months of radio-tracking would still miss most of the winter 2021-2022 timber harvest season and bird responses to it. If we had additional funds to offset unanticipated costs on Activities 1, 2, and 3, then we could complete all 3 Activities as planned, but with a 1-year delay.

Amendment Request as of 12/27/2020
Due to DNR hiring restrictions related to COVID-19, we are unable to hire seasonal personnel for the field work under the DNR service contract. In order to continue project progress and complete monitoring efforts of marked grouse, we are requesting to move funding for to be hired seasonal field personnel from the DNR service contract to the University of Minnesota personnel budget. The amount we are requesting to move is $40,064. This request has no impact on the workplan or deliverables.
Amendment Approved by LCCMR **1/13/2021**

Amendment Request as of 3/1/2021
Based on conversations with LCCMR staff after submission of the September 1, 2020 report, we are requesting a 1-year extension for Activities 1, 2, and 3 due to COVID-impacts on field activities during spring 2020. We are completely repeating the spring 2020 field season to accomplish work for Activities 1 and 3 in spring 2021. Additionally, the bulk of our capture efforts to radiomark spruce grouse for Activity 2 will be completed 1 year later than planned, so we will need time additional time to complete this activity as well.

Amendment Approved by LCCMR 3/29/2021

Third Update March 1, 2021
We have hired technicians for the March/April 2021 fecal pellet surveys that were not completed in winter 2020. Winter collection of fecal pellets for genetic analysis will occur during March/April 2021.
In fall 2020, we captured and marked 22 spruce grouse, with several more birds captured during winter, increasing our total sample numbers to 59. Throughout the year, we monitored locations of the marked birds. During hunting season, we received 101 feather submissions for genetic analysis. UMGC has reported success extracting DNA from fecal pellets, but success was higher with feather samples. We would therefore like to work with hunters again in Fall 2021 (through Jan 2022) to augment the sample of feathers, and use fecal pellet samples to fill geographic gaps in data obtained from feathers.

On the Project Budget Sheet, we show a $19,600 overspend on in-kind contributions. The in-kind contribution was higher than expected because 1) we could not capture birds during the spring of 2020 because of the Stay-at-Home-Order and tried to recover from that unplanned interruption in field work, and 2) we could not immediately hire a full-time replacement for a departing technician because of the state-hiring freeze. Thus the co-PI worked significant extra hours to address these COVID-related project issues to attempt to mitigate failure of the project. This additional in-kind will not be recovered, but rather is an unanticipated investment (and gift) of time by the co-PI. The impact of these extra hours by the co-PI is that the project remains on track to be successful IF additional funding can be secured. If it cannot be secured, than the impact is that the project will be the best it possibly could be in the face of COVID and without additional support.

Fourth Update September 1, 2021
We secured an additional $74,578 from the Minnesota Department of Natural Resources to complete our objectives on Activity 2. We have completed Outcome 1 for both Activity 1 and Activity 2. We continue to make progress toward the remaining outcomes on all 3 Activities, including tracking radiomarked birds and sending samples for genetic analysis to UMGC.

Fifth Update March 1, 2022
We advertised for a post-doctoral associate to assist with analysis of data collected for all 3 Activities, with intent to begin a new hire on 1 June 2022. We continue to monitor radio-marked birds for Activity 2. We completed data collection for Activity 3 Outcome 1 and sent samples to University of Minnesota Genomics Center to complete genetic analysis for Activity 3 Outcome 2.

Sixth Update September 1, 2022
Post-doctoral associate was hired and began 1 year appointment 1 July 2022. Analysis of the spruce grouse pellet survey data is underway by the post-doctoral associate. Genetics data from UMGC is still pending and analysis will begin when it is received. All tracking of radio-marked grouse supported by this grant has been completed.

Seventh Update March 1, 2023
The post-doctoral associate has drafted a manuscript for publication using the pellet survey data (objective 1). Analysis for objective 2 has been started and will continue in the next few months. We received genetic data from UMGC on 15 February 2023, which was later than anticipated. The post-doctoral associate will begin work on the genetics objective (3) now and will attempt to complete this objective for the final report in June.

Final Report between project end (June 30) and August 15, 2023
The post-doctoral associate ended his appointment with University of Minnesota -Twin Cities in mid-June 2023, upon taking another position. Prior to his end date, he submitted a manuscript for Activities 1 and drafted one for Activity 3 that will be submitted for peer-reviewed publication this summer; a third is underway on Activity 2 that will also be submitted (likely this fall). We also submitted a Final Report to the Minnesota Department of

Natural Resources, which will be made available online. The Summary of Findings for the Final Report is excerpted below:

- We completed a 4-year study (2019-2022) to examine spruce grouse occupancy of conifer forest patches, responses to timber harvest, and genetic connectivity in the boreal forest of northern Minnesota.
- Our occupancy results indicated that forest management practices that promote dense vegetation structure may benefit spruce grouse, especially a dense mid-canopy layer (5.0 – 15.0 m).
- Our telemetry data indicated that spruce grouse have lower survival after timber harvest, but that most harvested conifer stands were avoided prior to harvest, likely due to the sparse midstory vegetation structure in many of these mature stands. We suggest that reduced spruce grouse survival after timber harvest may be due to indirect effects of timber harvest, such as harvest-related changes in predator behavior or predator space use (e.g., edge effects, changes in predator density in nearby stands) rather than habitat loss.
- Our genetic data indicated that spruce grouse exist as a single interconnected population in Minnesota, with coniferous forest land cover and lower average temperatures during spring dispersal being the best predictors of gene flow. Therefore, climate change could potentially threaten the persistence of the single interconnected population.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1 Title: *Study wildlife use of forest stands through fecal pellet surveys*
Description: We will conduct ≥125 pellet surveys in conifer stands throughout northern Minnesota during winter when pellets contrast strongly against the snow. We will record the location and species type of all pellets encountered along transects. We will measure forest characteristics at the stand level including stand type, vegetation structure, and age or size class. We will also use GIS mapping software to determine mean distance between forest patches, mean patch size, patch density, patch contiguity or similar characteristics related to forest patch connectivity. These data will help understand wildlife use of forest stands that vary in size, composition, and arrangement, as well as characteristics of patches that are not used.

ACTIVITY 1 ENRTF BUDGET: $ 67,932

Outcome	Completion Date
1. Fecal pellet surveys (125) along transects in conifer stands during winter	*April-2021*
2. Determine how wildlife use forest stands and how this is related to stand characteristics and isolation	*June 2023*
3. Make recommendations for forest planning to promote landscapes that wildlife can use after harvest or habitat loss	*June 2023*

First Update March 1, 2020
We have hired 2 seasonal technicians to conduct pellet surveys 2 March - 30 April 2020 throughout northern Minnesota.

Second Update September 1, 2020
We completed two repeat fecal pellet surveys of transects in the western portion of the survey region before EO 20-20 took effect, encompassing ~50% of the planned survey region. Importantly, our 3rd repeat survey was not completed for most of these survey transects, which is necessary for the Multi-Species Occupancy Modeling (MSOM) approach we plan to use to determine how wildlife use forest stands as it relates to stand

characteristics and isolation. This modeling approach is groundbreaking, and alternative analytical options have not yet been developed that would be able to make use of just two surveys in a detection framework. A third survey in the same field season is necessary to meet the assumptions of the MSOM analysis so that we can make recommendations for forest planning to promote landscapes that wildlife can use after harvest or habitat loss.

We plan to repeat the pellet surveys in spring 2021, if we do not face additional obstacles stemming from the pandemic and associated hiring freeze. Assuming that we are able to hire seasonal help to collect the data in spring 2021, we propose that we use funds previously planned for Activity 2 to complete Activities 1 and 3 this fiscal year. An additional season for Activity 1 (which also serves to accomplish Activity 3) will cost $31,838, which includes additional fleet costs for staff to ride in separate vehicles to prevent the spread of COVID-19. If additional funds could be available for use in July 2021, they could be applied to Activity 2 thereafter. Under this scenario, our products for Activity 1 will be delayed by 1 year, with a revised completion date of December 2022, but we should be able to deliver the originally proposed products. If additional funds are not available, we would have to choose whether to spend available funds on Activities 1 and 3, at a cost to Activity 2, or compromise deliverables on all 3 Activities. We would prefer to realize some of our proposed deliverables, but many uncertainties make planning difficult at this stage. In particular, repeating the spring season for Activity 1 requires that the hiring freeze ends and that we are able to hire seasonal help to begin Mar 2021. As currently planned, a post-doctoral associate would work on the MSOM analysis, interpretation of wildlife use of forest stands, and recommend forest planning for wildlife after timber harvest or habitat loss. This also assumes that the hiring freeze does not preclude hiring a post-doctoral associate after the data are collected next spring.

Third Update March 1, 2021
We have hired 2 seasonal technicians to conduct pellet surveys 1 March – 29 April 2021. We need to repeat the entire spring 2020 field season due to COVID-19 impacts on the study. A second field season was not originally planned.

Fourth Update September 1, 2021
Fecal pellet surveys were completed at 290 transects throughout spruce grouse range in Minnesota during the March/April 2021 season. Fecal pellet surveys in 2021 covered the spruce grouse range more intensively than the survey in 2020, which was cut short by the Stay-at-Home Order. During spring 2021, we also measured forest characteristics at the stand level at each of 2 plots on 226 transects throughout the central and eastern part of spruce grouse range in Minnesota. This complements the 217 forest stand measurements completed at 119 survey transects in the western portion of the spruce grouse range in 2020, before the Stay-at-Home Order. Thus, forest characteristics were measured at stands throughout the spruce grouse range during the 2 year period.

Fifth Update March 1, 2022
We are advertising for a post-doctoral associate to help with analysis of data for this activity as part of Outcomes 2 and 3.

Sixth Update September 1, 2022
Post-doctoral associate has been hired and is in the process of analyzing the data collected. The summary report and recommendations for forest planning will be based on these analyses.

Seventh Update March 1, 2023
A manuscript for this objective has been completed and will be submitted to a peer-reviewed journal shortly. Outcomes 2 and 3 for this objective are addressed in this manuscript, completing all 3 outlined outcomes in preparation for the final report.

Final Report between project end (June 30) and August 15, 2023

A manuscript entitled “Forest structure mediates occupancy and extinction of early successional forest vertebrates on the training edge of the boreal forest” has been submitted for peer-review to Forest Ecology and Management. Below a summary of findings is excerpted from the MNDNR Final Report,

- Our models suggest mid-canopy density was the key stand-scale determinant of spruce grouse occupancy and persistence, which is likely related to cover from predators and thermal protection.
- Forest structure may be a stronger determinant of spruce grouse habitat selection than stand type, which may explain the widely varying descriptions of stand types used by spruce grouse in the literature.
- We also found deciduous forest cover to be a key factor limiting the range of spruce grouse.
- The strongest predictors of both occupancy and local extinction probabilities for spruce grouse were landscape-scale land-cover variables and mid-canopy density (5-15 m).
- Temperature was a predictor in the most-supported multivariate extinction model but had a small effect relative to land cover, road density, and canopy structure.
- Road densities were positively related to spruce grouse extinction probability. Road densities may be positively associated with predator density, which can affect prey species occurrence (Boan et al. 2014). Road density may also be correlated with hunter accessibility and localized harvest pressure near roads. Areas with fewer roads may promote spruce grouse persistence.
- Spruce grouse and ruffed grouse occurrence aligns with a coniferous-deciduous forest gradient with co-occurrence most probable in the mixed coniferous/deciduous transition zone. The land cover-based gradient coincides with the large-scale latitudinal transition from northern boreal forests to southern deciduous forests. This transition zone is expected to shift northward as climate warms and deciduous forests replace boreal forests (Taylor et al. 2017). Our work suggests that ruffed grouse are likely to replace spruce grouse as a result of changing habitat conditions in the study area.

ACTIVITY 2 Title: *Study spruce grouse movements after harvest of stands where they were captured*
Description: We will capture 70 spruce grouse in black spruce and jack pine stands scheduled for timber harvest and attach radiotransmitters. We will monitor movements before, during, and after timber harvest of black spruce in winter and jack pine in summer. Birds will be marked and monitored to capture responses to timber harvest during different portions of the life cycle. During winter, spruce grouse face thermoregulatory challenges, dietary constraints, and contrast strongly against the snow. During summer, spruce grouse have broods that may constrain responses of females. By monitoring spruce grouse responses during both winter and summer, we will gain a more complete understanding of how birds respond to habitat loss at different times of year, and whether loss of habitat within a substantial portion of the home range is a short-term or more chronic stressor. We will also determine if spruce grouse move to the nearest conifer forest stand, or farther, and whether there is substantial mortality risk of moving in an open landscape. We will examine movements before, during, and after timber harvest and examine areas used during these periods.

ACTIVITY 2 ENRTF BUDGET: $ 220,531

Outcome	Completion Date
1. Capture spruce grouse (70) in stands planned for harvest and attach transmitters	Nov 2021
2. Monitor spruce grouse movements following timber harvest	April 2022
3. Recommend configuration of stands to optimize wildlife response to timber harvest	June 2023

First Update March 1, 2020
Two seasonal technicians were hired and began work 23 November 2019 to capture, radio-mark, and track spruce grouse in or near black spruce and jack pine stands planned for harvest during winters 2019-2020 and

2020-2021 and summers 2020 and 2021. We have captured 8 spruce grouse to date and expect most captures to occur in the spring as birds begin spending more time on the ground. As of February 14, we have located the birds 91 times and obtained habitat plot measurements at their locations. We also have 13 additional locations and habitat data for unmarked birds located in or near the stands. Additionally, we are searching stands planned for timber harvest for pellets to examine use of stands before harvest when birds could not be located and captured before harvest. Sixteen stands have been searched and 8 stands have been harvested. Work will continue on this activity through 2022.

Second Update September 1, 2020

As of 27 March 2020, we had captured and marked 18 spruce grouse, but all capture and tracking efforts halted during the Stay-at-Home Order, when we had hoped to capture most of the 70 planned birds. Since the resumption of fieldwork in May after the spring capture window ended, we have utilized a variety of approaches (i.e., chick calls, pointing dogs) to attempt to mark birds. To date, we have captured and radio-marked 33 birds and have obtained 538 bird locations with habitat plot measurements. Additionally, we have completed habitat measurements at 30 timber stands scheduled for harvest. Twelve stands have been harvested in the Big Falls study area and 16 in the Norris Camp study area.

We had planned to capture and radio-mark most of sample of 70 spruce grouse in March and April 2020, with a smaller capture effort in 2021 to offset birds lost due to expiration of transmitters and bird mortality. This would have given us a large sample of birds to radio-track during the summer 2020, winter 2020-2021, summer 2021, and winter 2021-2022 timber harvest seasons, with a gradual attrition of the sample and less tracking effort needed over time. This large sample would produce robust sample sizes on which to base our recommendations for stand configuration.

Because we missed the first and largest planned capture season due to COVID-19, we now plan to capture and radio-mark most of the birds next spring, when spruce grouse are most easily captured. We will deplete currently available funds to track birds in Oct 2021, so birds marked in Apr 2021 can be tracked for only 6 months (25-50% of the expected radio life) with existing funds. This potential funding lapse will occur before the winter 2021-2022 timber harvest season, cutting our planned winter tracking by a full season. To deliver the originally planned product, we will need additional funds ($82,420) to support 2 technicians (salary, fringe) and fleet costs for the following year, after we take into account the funds diverted to hire technicians to accomplish Activities 1 and 3 in FY21 (Total Additional Request = $82,420 for all 3 activities). Our products for Activity 2 would then have an expected completion date of December 2023. Alternatively, we could not move funds from Activity 2 to Activities 1 and 3, but this will only result in 2.5 months of additional tracking, still falling short of the winter 2021-2022 timber harvest season. The consequence of this less favored alternative would be an inability to meet deliverables for Activities 1, 2, and 3. If additional funds are not available to support Activity 2, we will likely have too small a sample to be able to come to robust conclusions for winter timber harvest. We will be able to look at responses to timber harvest in the summer of 2021, but will not fully realize the potential information that could be obtained from radios that can last >1 year. Fewer birds tracked for fewer seasons will impact our ability to make recommendations for configuration of stands for wildlife benefits.

Third Update March 1, 2021

During fall 2020, we marked 22 spruce grouse as they came to roads for grit. We also marked several chicks of collared birds when they became large enough to carry a transmitter. To date, our sample is comprised of 59 birds. We have 1,392 bird locations (3–80 locations/bird) with habitat measurements. We currently have 27 radiocollared spruce grouse that we are tracking. Mortality has been due to hunter-harvest (8) and predators (20), which is expected for gamebirds. We could not determine a cause of death for a few birds, but collected carcasses for future necropsy. We are attempting to secure additional funding so that we can continue tracking birds for the life of the transmitters. We are facing budget shortfalls due to having to repeat the spring 2020 season and deploying transmitters later than originally planned. In order to offset these issues, we are seeking

additional funds from the DNR and American Bird Conservancy. If we do not receive additional funds, we will fall short of meeting our objectives on Activity 2. We are requesting an additional $75,000 from the DNR and an additional $20,000 from ABC.

Fourth Update September 1, 2021
As of 3 August, we had captured and radio-marked 77 spruce grouse, meeting our goal of 70 spruce grouse for this activity. We secured $74,578 from DNR to continue the study through the spring of 2022, which offsets additional costs due to COVID. We did not receive additional funds from ABC. We anticipate meeting our objectives for Activity 2 with this new funding. As of 3 August, we had visited 2,454 bird locations and collected forest stand measurements at these locations.

Fifth Update March 1, 2022
We captured and marked 23 additional spruce grouse since the last report and continued to track them throughout the fall and winter. Unfortunately, timber harvest has been minimal near our marked birds this winter, which will limit our conclusions about timber harvest effects on marked birds.

Sixth Update September 1, 2022
All monitoring supported by this grant has been completed. Investigators used additional funding secured from the DNR to continue monitoring this spring to increase dataset and complete objectives for this activity. Analysis of data is underway and will be completed by post-doctoral associate.

Seventh Update March 1, 2023
The post-doctoral associate has identified birds with home ranges near harvested stands in preparation for the final analysis of movements in response to timber harvest. Analysis and writing will continue on this objective for the final report.

Final Report between project end (June 30) and August 15,-2023
A manuscript is in preparation for peer-reviewed publication. A summary of findings for this activity is excerpted below from the MNDNR Final Report, which will be made available online,

- Survival of spruce grouse in and near harvested stands declined after harvest.
- Most marked spruce grouse were near harvested stands, but spruce grouse were rarely within harvested stands even before harvest.
- Spruce grouse home range overlap with harvested stands decreased after harvest.
- Avoidance of many harvested stands before harvest indicates that many of these stands were not suitable for spruce grouse before harvest. Many stands mature enough to harvest in Minnesota may lack the dense vegetation structure necessary to support spruce grouse.
- Reduced survival near harvested stands might occur indirectly through edge effects or from predator displacement from harvested stands producing greater predator densities in nearby stands used by spruce grouse.
- Timber harvest may increase spruce grouse mortality but may also be necessary at some level to promote regeneration of stands with denser vegetation structure that supports spruce grouse (i.e., to avoid over-maturation of forests). We recommend maintaining areas with dense conifer forest structure for spruce grouse near harvested stands to provide cover from predators after harvest, while also being of sufficient size and structure to meet foraging, nesting, rood-rearing, and other needs of spruce grouse throughout the year.

ACTIVITY 3 Title: *Examine large scale connectivity of the forest using genetics of spruce grouse*
Description: We will collect >300 spruce grouse pellets during winter surveys to obtain DNA and perform a

landscape-level analysis of forest connectivity in the boreal forest region of Minnesota. Genetics allow the identification of long-term barriers to movement at a regional scale. Genetic structure quickly dissipates when barriers to movement are removed and individuals mix among previously isolated areas. We will examine existing boreal forest connectivity to identify any deficiencies in connectivity that currently exist. This information can be useful in forest planning to identify areas that might be more sensitive to further reductions in connectivity and also to provide a benchmark for future comparison.

ACTIVITY 3 ENRTF BUDGET: $ 61,538

Outcome	Completion Date
1. Collect spruce grouse fecal pellets (>300) during winter	*April 2021*
2. Laboratory analysis of spruce grouse genetic samples	*June-2022*
3. Landscape analysis of genetic samples to examine large scale connections in the forest	*June 2023*

First Update March 1, 2020
To date, we have submitted 117 fecal pellet samples and 13 feather samples to the University of Minnesota Genomic Center (UMGC) for genetic analysis. UMGC has reported successful isolation of spruce grouse DNA from the samples based on amplification with microsatellite loci designed for gallinaceous species. We anticipate collecting additional samples during the upcoming pellet survey season beginning 2 Mar 2020.

Second Update September 1, 2020
In addition to the 130 samples previously reported, we collected 37 fecal pellet samples and 5 feather samples during fieldwork in winter 2020. We have also been collecting feathers from all 33 captured birds in Activity 2, as well as 7 eggshell membranes from hatched nests and 1 unhatched chick of radio-marked birds. However, our inability to survey the eastern portion of the survey region during the pandemic, where spruce grouse densities are higher, and collect fecal pellet samples, produced a deficit of ~100 samples. We plan to repeat the survey season in spring 2021, which would serve to complete both Activities 1 and 3 as originally described. We will not be able to meet the planned deliverables without another field season. Our completion date for the originally proposed deliverables would be delayed until June 2022. Without additional funding and the ability to hire 2 technicians to begin in Mar 2021, we would either not be able to complete both Activities 1 and 3, or have to use funds dedicated to Activity 2, further compromising results for Activity 2. Another field season for Activity 3 (and Activity 1) will cost $31,838. The hiring freeze could also affect our ability to hire a post-doctoral associate to assist with the landscape analysis of genetic samples and interpretation of large-scale connections in the forest.

Third Update March 1, 2021
UMGC has reported success with extraction of DNA from fecal pellet samples. However, the DNA quality is lower for fecal pellets than it is from feather samples. We received 101 feather submissions from hunters during fall 2020 that will be included in the genetic analysis. We hired 2 seasonal technicians to collect pellet samples during 1 March 2021– 29 April 2021. We would like to work with hunters again in fall 2021 to increase our sample size of feathers for the analysis, and then use fecal pellet samples to address deficiencies in geography among the feathers. This will produce the best results for the study and help keep costs down.

Fourth Update September 1, 2021
We sent another shipment of samples to UMGC in July 2021. This shipment included 214 feather samples and 51 offspring samples (eggshell membranes and unhatched embryos) from our radio-marked birds. These samples amplify more reliably in the laboratory than fecal pellet samples, so we are focusing on the hunter-submitted feathers from 2020 and 2021, and samples derived from radio-marked birds, to ensure that we are as cost-effective as possible with the remaining funds. We anticipate that these approved changes will enable us to meet project outcomes on Activity 3, which otherwise, would be difficult to meet.

Fifth Update March 1, 2022
We submitted 88 additional feather samples from hunter-harvested and radio-marked birds, 7 eggshell membranes, and 1 tissue sample to the University of Minnesota Genomics Center in Dec 2021. Thus, we exceeded our goal of 300 genetic samples for Activity 3 and are now working on Outcome 2. We also began advertising for a post-doctoral associate to begin analysis of sample genotypes on 1 June 2022 to complete Outcome 3.

Sixth Update September 1, 2022
Genetic analysis of samples is still underway at the University of Minnesota Genomics Center. Analysis will begin when the results are received.

Seventh Update March 1, 2023
The second outcome for this objective was completed on 15 Feb 2023, later than anticipated (15 Nov 2022). We will initiate work for outcome 3 now and hope to complete this analysis in time for the final report in June 2023.

Final Report between project end (June 30) and August 15, 2023
A manuscript is nearing submission for peer-reviewed publication. We summarize findings below in an excerpt from the MNDNR Final Report which will be made available online,

- The spruce grouse population in Minnesota currently exists as a continuous population with no distinct spatial demes. Distinct spatial demes would indicate that gene flow is restricted and that barriers to connectivity and movement exist that fragment the population into separate subpopulations.
- Gene flow was positively related to lower spring temperature during dispersal and greater coniferous forest land cover.
- Two approaches to connectivity modeling gave complementary perspectives of genetic connectivity, highlighting greater potential for gene flow in the northeast and northwest than central portions of the study area. Both indicated several partial barriers to gene flow, including Red Lake and the Mesabi Range.
- Forest management to promote gene flow through conifer forest cover may influence the connectivity of this region for spruce grouse with climate change. Our data indicate the central part of the study area may be most vulnerable to climate change impacts to gene flow. The cooler northwestern and northeastern portions of spruce grouse range in Minnesota may provide climate refugia and maintain some spruce grouse gene flow and connectivity (Huntingford and Lowe 2007; Anderson et al. 2020).
- This research highlights climate change and associated changes in conifer forest cover as important considerations for spruce grouse population connectivity at their southern range periphery.

IV. DISSEMINATION:

Description:
Our findings will be communicated with state (e.g. DNR) and federal (e.g. USFS) land managers, as well as agencies tasked with forest management and timber harvest (counties, industry). Findings will be presented at state, regional, and national meetings (e.g., SAF, TWS) as appropriate given the results. Publications will be produced for peer-reviewed journals, outreach newsletters, and annually for the DNR's Summaries of Wildlife Research Findings. Media outreach will also be pursued.

The Minnesota Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement Guidelines.

First Update March 1, 2020
No activity to date.

Second Update September 1, 2020
We prepared a progress report for the DNR's Wildlife Research Summaries, which should be available on the DNR website this month. Additional information about how to contribute samples for the genetics study (Activity 3) is available in the DNR Hunting Regulations book and the Grouse Hunting page on the DNR website.

Third Update March 1, 2021
The progress report for the DNR's Wildlife Research Summaries is not yet available on the DNR website due to staffing shortages related to the hiring freeze and redeployments to assist with vaccine distribution. This report will be posted, but timing is uncertain.

Fourth Update September 1, 2021
The progress report for the 2019-2020 season is now available on the DNR website with DNR's Wildlife Research Summaries at https://files.dnr.state.mn.us/wildlife/research/summaries/2019/upland/2019upland003.pdf The ENRTF logo is included in the report.

We anticipate another press release this fall to provide information about how hunters can contribute to the genetics study (activity 3) by submitting feather samples from birds they harvest. Information continues to be posted on the DNR Grouse Hunting page and also in the 2021 Hunting Regulations book.

Fifth Update March 1, 2022
We issued 2 press releases to engage the participation of hunters in the study.

Sixth Update September 1, 2022
No additional dissemination was done during this period.

Seventh Update March 1, 2023
No additional dissemination was done during this period.

Final Report between project end (June 30) and August 15, 2023

- A freelance reporter requested the Final Report on the study at the end of June for a piece that will come out early next year. We provided the MNDNR Final Report that included findings for all 3 Activities.
- We will contact hunters that submitted samples for the genetic objective and share the study results with them.
- We will also present our findings to wildlife managers at regional meetings, at the Midwest Fish and Wildlife Conference in South Dakota in late January 2024, and at the Minnesota Chapter of The Wildlife Society in February 2024.
- One manuscript has been submitted (Activity 1) and at least 2 additional manuscripts will be submitted for peer-reviewed publication in scientific journals in 2023.
- Genetic connectivity results will be included in a presentation at The Wildlife Society Annual Meeting in Louisville, KY, November 2023.

V. ADDITIONAL BUDGET INFORMATION:

A. Personnel and Capital Expenditures

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

Explanation of Use of Classified Staff: NA

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1

Enter Total Estimated Personnel Hours for entire duration of project: 2,080	Divide total personnel hours by 2,080 hours in 1 yr = TOTAL FTE: 1.0

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

Enter Total Estimated Contract Personnel Hours for entire duration of project: 7,800	Divide total contract hours by 2,080 hours in 1 yr = TOTAL FTE: 3.75

VI. PROJECT PARTNERS:

A. Partners outside of project manager's organization receiving ENRTF funding

Name	Title	Affiliation	Role
Charlotte Roy	Research Scientist	MNDNR	Oversee field studies

B. Partners outside of project manager's organization NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Various staff	Foresters, Wildlife Managers	MNDNR	Identify timber stands for inclusion in study

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

This research will provide information to improve timber harvest planning in ways that are compatible with conservation of wildlife populations. We currently lack information to manage wildlife strategically with changing forest composition and predicted loss of spruce-fir forests from Minnesota. This study will reduce that information gap. Findings and results will be communicated to foresters and wildlife staff at the Department of Natural Resources, U. S. Forest Service, and private industry through presentations at professional meetings and peer-reviewed publications.

VIII. REPORTING REQUIREMENTS:

- Project status update reports will be submitted March 1 and September 1 each year of the project
- A final report and associated products will be submitted between June 30 and August 15, 2022

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet N/A
D. Acquisition, Easements, and Restoration Requirements N/A
E. Research Addendum

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2019 Budget Spreadsheet
Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 03e
Project Manager: Julia B Ponder
Project Title: Spruce Grouse: Sentinels for Boreal Forest Connectivity
Organization: University of Minnesota
Project Budget: $350,000
Project Length and Completion Date: 3 years, 30 June 2023
Today's Date: 31 July 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 127,447	$ 123,927	$ 3,520
Project management (J Ponder) 5% effort (75% salary, 25% fringe) for 2 years; UM postdoc for 12 months *$4000/mo. plus 22.4% fringe; seasonal field technicians $27,324 + 31.8% fringe ($40,064)			
Professional/Technical/Service Contracts			
DNR contract for field data collection (field technicians at $2,782/mo.($85,126); fleet for 43 mos. @$1,000/mo. ($43,000); lodging and per diem for field crew ($29,756); 3 telemetry flights to find missing birds @$1,000 per flight ($3,000); direct and necessary costs ($25,841)	$ 186,722	$ 186,711	$ 11
UMN Genomics Center: 300 samples @ $44.88 per sample ($13,660))	$ 19,182	$ 17,623	$ 1,559
Equipment/Tools/Supplies			
Supplies to collect samples; 70 VHF transmitters @ $200 each ($14,000); tracking equipment ($7,000); misc supplies ($14,379)	$ 16,649	$ 16,649	$ 0
COLUMN TOTAL	$ 350,000	$ 344,910	$ 5,090

OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: Timber harvest on county lands will be conducted with existingfunds and equipment		TBD	$ -	
State: UM indirect costs at 54%		$ 189,000	$ 186,251	$ 2,749
In Kind: DNR funds for additional monitoring (Activity 2)_		$ 116,035	$ 116,035	$ -
In kind: Matching funds for Charlotte Roy (MDNR, 0.10 FTE (9600)*2.5 years = $10,000)		$ 100,478	$ 100,478	$ -

PAST AND CURRENT ENRTF APPROPRIATIONS	Amount legally obligated but not yet spent	Budget	Spent	Balance
Current appropriation: No current appropriation		NA	$ -	
Past appropriations: No past appropriation		NA	$ -	