2016 Project Abstract
For the Period Ending June 30, 2019

PROJECT TITLE: Evaluation of Tree Retention Guidelines Pertaining to Wildlife
PROJECT MANAGER: Alexis Grinde and Gerald Niemi
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2016, Chp. 186, Sec. 2, Subd. 03p
APPROPRIATION AMOUNT: $ 232,000
AMOUNT SPENT: $232,000
AMOUNT REMAINING: $0

Sound bite of Project Outcomes and Results
There is a positive relationship between tree retention and wildlife diversity. Trees retained in a clumped configuration are most beneficial for small mammal communities, maintain bird diversity over time, and significantly increase the relative abundance of several breeding bird species post-harvest.

Overall Project Outcome and Results
Forest management is increasingly focused on maintaining ecological functions, including maintenance of biodiversity and wildlife habitat. In 1998, the Minnesota Forest Resources Council (MFRC) established Minnesota's Forest Management Guidelines, which were intended to reduce the potential for negative environmental impacts resulting from forest harvesting. The current guidelines recommend that 6-12 trees per acre or 5 percent of the harvest area in 0.25 acre clumps or greater be retained (left uncut) for wildlife and biodiversity benefits. The spatial arrangement of retained trees influence habitat suitability for wildlife species, but there is a lack of information on what configuration of tree retention will maximize wildlife benefits. To examine and quantify the benefits of tree retention after logging on Minnesota's wildlife, we measured breeding bird and small mammal diversity by conducting systematic surveys at four experimental study areas and 69 sites that had been harvested between three and 15 years previously. We then quantified the habitat characteristics including tree retention density and configuration at harvest sites. Our results showed there is a positive relationship between tree retention and wildlife diversity. The clumped configuration was most beneficial for small mammal communities. Stands with clumped tree retention also maintained bird diversity over time and significantly increased the relative abundance of several breeding bird species. Overall, the results indicated that the current MFRC guidelines are beneficial for wildlife and increase the diversity and total abundance of bird and small mammal species that use forest stands post-harvest. We recommend that the MFRC continue to promote clumped tree retention, or the use of a combination of clumped and scattered retention, to mitigate harvest-related impacts to Minnesota's wildlife. The results of this project add to the scientific basis for MFRC's forest management guidelines and provide support for sustainable management of Minnesota's forest resources.

Project Results Use and Dissemination
The results of this project have been presented at a variety of workshops and conferences:

- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 11, 2018.
- The Minnesota Chapter of The Wildlife Society Meeting, St. Cloud Minnesota, February 12-14, 2018.
- Charting the Future for Northern Forest Birds: Takin it to the Tweets workshop in Ashland, WI, April 16-17, 2018.

- Forestry for Lake States Birds, Long Lake Conservation Center, June 22-23, 2018.
- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 10, 2019 and The Minnesota Chapter of The Wildlife Society Meeting, Duluth Minnesota, February 19-21, 2019.
- The results of this report were presented to the MFRC on March 14th, 2019 and the PDF version of the presentation is included with the final report submission.
- The results of this project were featured in NRRI's newsletter and can be found here: https://www.nrri.umn.edu/natural-resources-research-institute/news/tree-retention
- We are in the process of completing two peer-reviewed manuscripts for this project and plan to have them submitted by the end of the year; the manuscripts will be available on NRRI's website after they are published.
- The final report will be posted on the NRRI website.
- Results from this work will also be used by the MFRC during the next revision of the guidelines, contributing to the scientific basis for forest management guidelines to sustainably manage Minnesota's forest resources.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2016 Work Plan

Date of Report: August 15, 2019

Final Report

Date of Work Plan Approval: June 7, 2016

Project Completion Date: June 30, 2019

Does this submission include an amendment request? No

PROJECT TITLE: Evaluation of Tree Retention Guidelines Pertaining to Wildlife

Project Manager: Gerald Niemi

Organization: Natural Resources Research Institute, University of Minnesota Duluth

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Location: Statewide

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$232,000**
	Amount Spent:	**$232,000**
	Balance:	**$0**

Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 03p

Appropriation Language:

$232,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Natural Resources Research Institute in Duluth to assess the effectiveness of the Minnesota Forest Resources Council tree retention guidelines in sustaining Minnesota's wildlife populations, by quantifying and evaluating the impacts on birds, small mammals, and amphibian diversity. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Evaluation of Forest Tree Retention Guidelines Pertaining to Wildlife

II. PROJECT STATEMENT:

We propose to examine and quantify the benefits of tree retention after logging on Minnesota's wildlife. The primary goal of forest management is increasingly focused on maintenance of biodiversity, compared to a historic emphasis on timber production alone. In 1998, the Minnesota Forest Resources Council (MFRC) established Minnesota's Forest Management Guidelines (http://mn.gov/frc/documents/council/site-level/MFRC_Forest_Mangement_Field_Guides_2014.pdf), which were intended to reduce the potential for negative environmental impacts resulting from forest harvesting and management activities on all forest lands in the state. Recommendations to retain trees during harvesting were considered key to sustaining wildlife species of greatest conservation concern (http://www.dnr.state.mn.us/cwcs/index.html), including many mammals, birds, and amphibians. Applications of guidelines during harvesting operations are voluntary, but if implemented, can mitigate impacts to wildlife habitat and help maintain healthy populations into the future. It is important to measure and assess the effectiveness of the retention guidelines to maximize the intended benefit to Minnesota's wildlife.

The current guidelines recommend that 6-12 trees per acre or 5 percent of the harvest area in 0.25 acre patches or greater be left uncut. The spatial structures of retained trees and their characteristics influence local habitat suitability for wildlife species and long-term forest structure including tree regeneration and native plant communities. Given this, spatial configurations of leave trees likely have important impacts on forest wildlife diversity, but there have been no experimental tests to determine the configurations that provide the greatest benefit to wildlife. Tree retention guidelines are grounded in best available scientific judgment, but there is little data available to quantify the long-term impacts or influence of the spatial configuration of "leave trees" on wildlife diversity. Evaluating these impacts will provide valuable information on which configurations are most beneficial for mitigating the impacts of forest harvesting to wildlife.

We will use monitoring data on leave tree retention collected by the Minnesota Department of Natural Resources (MNDNR) over the last decade to identify sites for this project. The MNDNR has monitored over 1000 harvest sites from 2000-2015 to determine the percentage of harvest sites that have implemented the recommended leave tree guidelines. We will use an experimental design that will allow us to assess differences in species diversity and composition between sites with contrasting (clumped or scattered) leave tree configurations. The study design is retrospective, covering a wide range of site conditions across the state and a post-harvest period of 3-15 years to determine the influence of leave trees over time. This approach will address common limitations of existing leave tree studies including insufficient sample size and duration of response.

We will utilize currently available high resolution LiDAR ("Light Detection and Ranging") data, an active remote sensing technology that uses laser light to detect and measure surface features, along with other high resolution imagery. This technology will be used to measure and quantify leave tree configuration and habitat characteristics of 60 harvest sites across the state. We will then conduct wildlife surveys, using a variety of sampling techniques and technologies to assess bird, mammal, and herptile diversity at leave tree sites. These data will allow us to assess the influence of spatial configurations of leave trees, time since harvest, habitat characteristics and landscape context.

The goals of this proposed project are to:

1) Quantify wildlife communities of birds, mammals, and herptiles, in relation to tree retention configuration following harvest; and
2) Improve ecological benefits of Minnesota's Forest Management Guidelines.

Project results will be summarized and presented to the MFRC for evaluation, and a summary report will be made available on NRRI's website and the MFRC website. The MFRC will use the information to either validate

the existing leave tree guidelines, or propose alternative guidelines that mitigate impacts on forest bird, mammal, and herptile species. The overall desired outcome of this project is to ensure that recommended tree retention guidelines are effective at mitigating harvest-related impacts on wildlife in the state. Ultimately, the information from our research will be transferred to loggers and resource managers during guideline training sessions.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2017:
As of December 1, 2016 the project is on track with the timeline outlined in the work plan. The majority of work completed thus far has involved the following: 1.) compilation of DNR leave tree data, and 2.) preliminary site selection based on age, size, cover type, and leave tree status.

Project Status as of July 1, 2017:
The project is on track with the timeline outlined in the work plan. The majority of work completed thus far has involved the following: 1.) compilation of DNR leave tree data, 2.) preliminary site selection based on age, size, cover type, and leave tree status, 3.) site visits, site assessment, and final site selection, and 4.) amphibian and breeding bird surveys.

Project Status as of January 1, 2018:
As of December 1, 2017 the project is on track with the timeline outlined in the work plan. We have completed site selection and the first year of field work including amphibian (spring), breeding bird (spring and summer), and small mammal surveys (fall).

Project Status as of July 1, 2018:
The project is currently on track with the timeline outlined in the work plan. We began the second year of field work this spring and summer including amphibian (spring), breeding bird (spring and summer). We are currently in the process of characterizing stand characteristics using a variety of imagery.

Project Status as of January 1, 2019:
The project is currently on track with the timeline outlined in the work plan. We completed all of the field work for the project, completed the characterization of stand variables, and are currently in the process of conducting our final analyses for the project.

Overall Project Outcomes and Results:
Forest management is increasingly focused on maintaining ecological functions, including maintenance of biodiversity and wildlife habitat. In 1998, the Minnesota Forest Resources Council (MFRC) established Minnesota's Forest Management Guidelines, which were intended to reduce the potential for negative environmental impacts resulting from forest harvesting. The current guidelines recommend that 6-12 trees per acre or 5 percent of the harvest area in 0.25 acre clumps or greater be retained (left uncut) for wildlife and biodiversity benefits. The spatial arrangement of retained trees influence habitat suitability for wildlife species, but there is a lack of information on what configuration of tree retention will maximize wildlife benefits. To examine and quantify the benefits of tree retention after logging on Minnesota's wildlife, we measured breeding bird and small mammal diversity by conducting systematic surveys at four experimental study areas and 69 sites that had been harvested between three and 15 years previously. We then quantified the habitat characteristics including tree retention density and configuration at harvest sites. Our results showed there is a positive relationship between tree retention and wildlife diversity. The clumped configuration was most beneficial for small mammal communities. Stands with clumped tree retention also maintained bird diversity over time and

significantly increased the relative abundance of several breeding bird species. Overall, the results indicated that the current MFRC guidelines are beneficial for wildlife and increase the diversity and total abundance of bird and small mammal species that use forest stands post-harvest. We recommend that the MFRC continue to promote clumped tree retention, or the use of a combination of clumped and scattered retention, to mitigate harvest-related impacts to Minnesota's wildlife. The results of this project add to the scientific basis for MFRC's forest management guidelines and provide support for sustainable management of Minnesota's forest resources.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Measure leave tree configuration and quantify habitat characteristics of 60 harvest sites with LiDAR.

Description:

We will compile monitoring data for over 1000 harvest sites collected by MNDNR Forestry department over the period 2000-2015. The DNR randomly selected these sites from all forest harvests, providing a representative sample of leave tree conditions throughout the state. We will use this data as a coarse filter to select sites that will be surveyed for wildlife. Utilizing the DNR monitoring data allows us to cover a range of leave tree configurations across the state for a post-harvest period of 3-15 years. For the site selection process, sites will be evaluated based on cover type, time since harvest, size, location, and be separated into two implementation categories: 1) clumped leave tree configuration, or 2) scattered leave tree configuration. A random-stratified design, with respect to time since harvest, will be used to select 60 sites. We will use area-restricted sampling, selecting sites in Cook, Lake, St. Louis, Koochiching, Itasca, Aitkin, Hubbard, Cass, and Beltrami Counties to minimize travel costs. The approach will allow for robust comparisons of the effect of leave tree configuration across a wide range of site conditions. Public and private lands were included in the monitoring data. Private landowners will be identified from previously collected information or county tax records, and then contacted to obtain permission to access the site.

After sites have been selected, we will use available LiDAR and high resolution imagery data to quantify habitat characteristics and spatial configurations of leave trees at each of the sites. LiDAR are capable of characterizing three-dimensional habitat structures that are significant to species with differing habitat preferences at scales that are comparable to, and often supersede, standard habitat ground measurements. Indeed, LiDAR has demonstrated ability in the assessment of three-dimensional vegetation structural characteristics that are important for wildlife, and have been employed to evaluate habitat for birds and mammals with predictive capabilities comparable to, or greater than, that of ground measurements. Potential variables to be used in the statistical modeling of wildlife habitat, based on LiDAR data, include canopy cover, canopy height, shrub cover, sub-canopy cover, leave tree structure, coarse woody debris, elevation, topographic index, and slope, among others.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 91,150
Amount Spent: $ 91,150
Balance: $ 0

Outcome	Completion Date
1. Identify 60 sample sites.	October 2016
2. Quantify habitat characteristics and spatial configurations of 60 harvest sites.	September 2018

Activity Status as of January 1, 2017:

Rob Slesak from the Minnesota Forest Resource Council worked to compile leave tree monitoring data. Leave trees have been monitored by the MNDNR for the following periods: 2000-2002, 2004-2006, 2009, 2011, and 2014- 2015.

A total of 769 sites have been monitored for leave tree status since 2000, we classified these sites based on age (time since harvest) and leave tree type. We chose to focus on stands that had aspen trees as the dominate cover type and were 20 acres to 40 acres in size based on the average harvest size scale of importance for wildlife. This selection process left us with a total of 234 sites, the average stand size of these sites was 28.3 acres, 147 of these sites had scattered leave trees, 75 sites had one or more leave tree clumps, and 12 sites had no leave trees. We then used GIS to further eliminate sites based on cover type surrounding the stands, confirmed leave tree status, and eliminated inaccessible sites. Site visits will occur in spring 2017 to assess and ground truth site characteristics.

Activity Status as of July 1, 2017:

Throughout spring 2017 we continued the process of site selection. We used aerial photographs along with a variety of available data from the DNR to assess forest composition and harvest characteristics for potential sites (Figure 1.1). We conducted site visits in April and May to assess access and site characteristics of 120 potential sites. We eliminated many sites after initial visits for a variety of reasons including accessibility, land ownership, and non-differentiated leave tree configuration. Overall, we identified 80 suitable sites that fit our criteria to survey for this project. Additionally, four experimental study areas in St. Louis County that included three replicates of three tree retention treatments (none, clumped, scattered) plus a control (unharvested) in our site selection. The study sites were harvested in 2010 and are aspen dominated ecosystems (Figure 1.2).

Figure 1.1. Representative leave tree sites from different age classes. A.) site harvested in spring 2017 with scattered tree retention, B.) site harvested in 2008 with scattered tree retention.

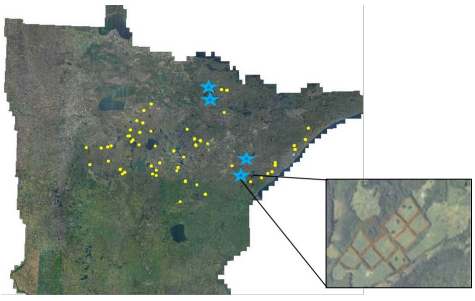

Figure 1.2. Leave tree sites surveyed for breeding birds in summer 2017. Stars represent study areas that are comprised of experimental harvest sites including three clumped, three scattered, three clearcut, and one control (unharvested) sites.

Activity Status as of January 1, 2018:

Preliminary analysis of year since harvest, landscape matrix, and leave tree configuration for all sites surveyed in 2017 has been completed. Characterization of harvest sites using LiDAR will begin in January 2018.

Activity Status as of July 1, 2018:

We have utilized a variety of historical and current imagery to accurately quantify stand characteristics, specifically we are focusing on stand size, stand age, height of retained canopy, and leave tree configuration. After initial assessments in 2017, we identified the need to further enhance the harvest stand boundaries for our leave tree sites prior to extraction of spatial metrics. We utilized historical imagery within Google Earth to manually digitize the stand boundaries of all sites to ensure accurate characterizations of retained canopy within harvested areas in subsequent steps. The sites selected for the project include a chronosequence of stand ages, however, because harvest often occur over the winter there were discrepancies in stand age, therefore we assigned a year of harvest to our sites using Landsat time series derived disturbance information.

To determine canopy characteristics we used a combination of LiDAR and historical Google Earth imagery. For stands harvested prior to the LiDAR acquisition that occurred between 2008 and 2012 for our study area, we utilized a LiDAR -derived 3m grid of maximum canopy height to identify areas of retained canopy at least 10m tall (Figure 1.3A). We assume that this height threshold includes most retained trees of interest to this project. We compiled these LiDAR pixels with ≥10m maximum canopy height into polygons representing retained canopy clumps and individual leave trees, which will later be used to characterize the amount and spatial distribution of retained canopy within harvests.

For sites harvested after the LiDAR acquisition, we used a multi-step approach to characterized retained canopy (Figure 1.3B). We first digitized the retained trees and clumps identified in Google Earth historical imagery. We used the first date of imagery following harvests whenever possible to minimize the chance of digitizing errors from understory regrowth. If this first post-harvest image was during leave-off, we opted for the next available leaf-on image for digitizing. As a second step to delineating retained canopy for these sites harvested post-LiDAR acquisition, we overlaid the digitized clumps/trees created in Google Earth with the pre-harvest LiDAR maximum height raster, and removed clumps that did not have a maximum height of 10m prior to harvest (with the assumption that the retained canopy in these patches would not meet the 10m threshold following harvest). To assess the accuracy and potential bias of our two methods of leave tree/clump delineation (manual vs. LiDAR -derived), we have established a protocol in which we will manually delineate retained canopy for a sample of sites which were harvested post- LiDAR and compare to the automated method using the LiDAR data. The final maps of stand boundaries, retained canopy for all sites, along with additional spatial information will be utilized to characterize landscape, stand, and within-site metrics to include in assessing the effects of leave tree configurations on wildlife species.

We have quantified 60 sites using the remote imagery methods described in the update. However, we conducted vegetation surveys in all stands this bird field season (June 2018) to ground truth our methods and model results. The next step will be to combine the field data with the imagery models to build our final models. In summary, activity 1 is not complete but we are close to finalizing the models for activity 1.

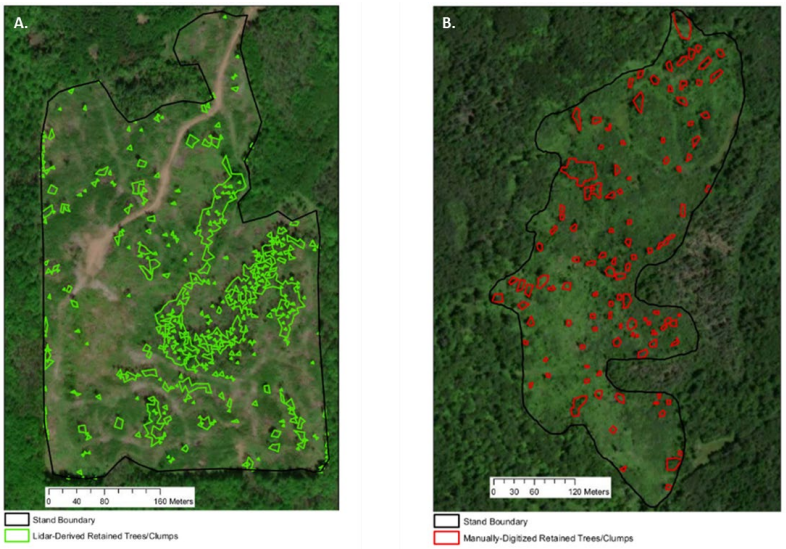

Figure 1.3. Representative leave tree stands A.) Example stand was harvested in 2012, before LiDAR aquistion, leave trees and clumps were derived using LiDAR B.) Example stand was harvested in 2014, after LiDAR acquisition, leave trees and clumps were manually derived using a multi-step process.

Activity Status as of January 1, 2019:
Activity 1 is complete. Recent work included a comparison of metrics developed from field data to those developed using remote imagery. This comparison showed relatively consistent quantification of tree retention and helped to identify potential inaccuracies associated with low-quality imagery for five sites. We have calculated the environmental (explanatory) variables at multiple scales: within stand variables that focus on tree retention characteristics of the stand (e.g., percent tree retention, spatial "clumpiness" of retained trees, leave tree species composition), stand-level variables (e.g., size, edge, age), and landscape variables that include cover type composition and development calculated within 100 m, 500 m, and 1000 m buffers around the stand. We are using a step-by-step model building procedure that allows us to account for factors at multiple scales that may influence species abundance and diversity within a stand but also minimize the number of models examined.

Final Report Summary:
This project utilized two study designs to assess the impacts of tree retention on wildlife; 1.) A previously established experimental design was used to evaluate the differences in response between clear-cut, scattered tree retention, and clumped tree retention as specified by the MFRC and, 2.) An observational chronosequence approach was used to evaluate bird response to varying tree retention levels and configuration of retained trees across stands that were 3-15 years post-harvest.

Experimental design. We utilized four experimental study areas located in St. Louis County that were designed to assess the effectiveness of the MFRC guidelines on biomass harvesting and leave tree retention (Kurth et al. 2014). The experimental study areas were located in aspen-dominated ecosystems that originated from clearcutting and ranged in age from 55 to 68 years. Treatments were replicated across the four experimental study areas using a 3X3 factorial design (Figure 1.4). Each study area was comprised of nine experimental treatment plots and one control plot that were each 10 acres (4.1 ha) in size. Treatments were designed to examine the effects of two factors, slash-retention and tree retention, each with three levels. Slash retention treatment levels were 0%, 20%, and 100% slash retention, while tree retention treatment levels were no tree retention (i.e., clear-cut without reserves), dispersed or scattered tree retention, and aggregated or clumped tree retention (Figure 1.5). Dispersed trees were prescribed with a density of 12 trees per acre and approximately 21 m spacing between trees across the designated stands. For aggregate green-tree retention, two roughly square or rectangular clumps with area approximately 0.1 ha (0.25 acre) each were located within

designated stands. Dispersed and aggregated green-tree retention and 20% slash retention were based on recommendations within the Minnesota Forest Management Guidelines (MFRC 2014). Harvest treatments were implemented in February, 2010; consequently, plots were 7 and 8 years old when wildlife surveys were conducted. This study design allowed us to use the treatments (tree retention and biomass retention) and the interactions of the treatments as predictor variables in our analyses.

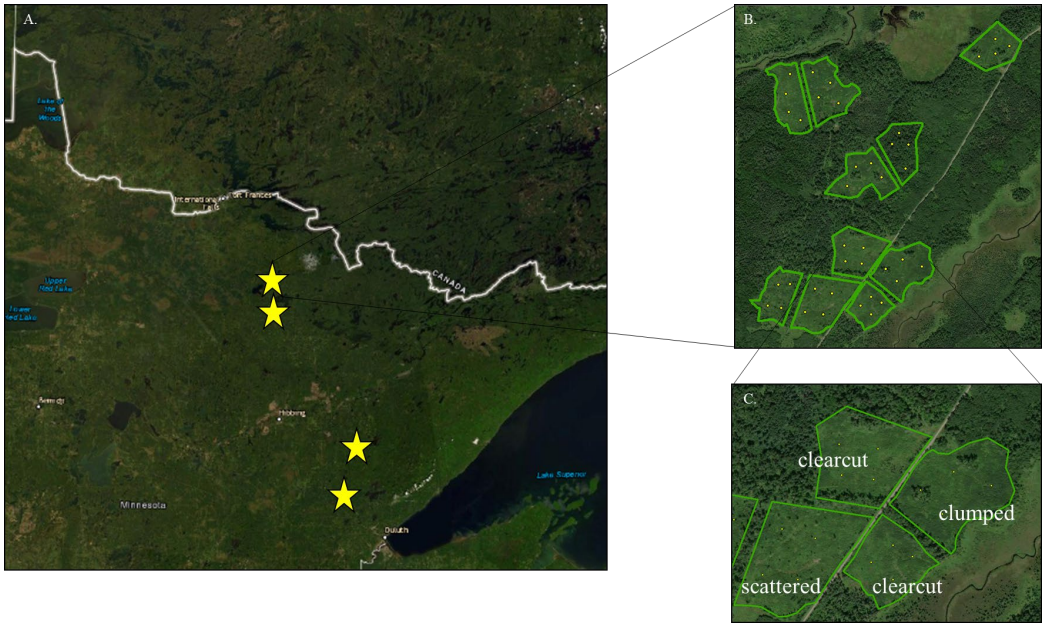

Figure 1.4. A.) Four experimental study areas located in St. Louis County, B.) Experimental study areas are composed of 10, 10 acre treatment plots, C.) Close-up of experimental treatment plots using Google Earth Imagery.

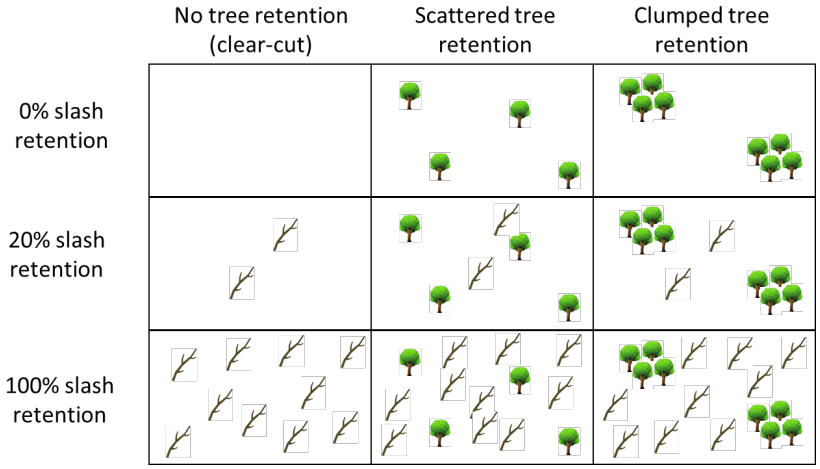

Figure 1.5. Experimental design for biomass and tree retention treatments implemented at the four study areas. Modified from Kurth et al. 2014.

Observational design. We used a chronosequence approach to assess how tree retention impacts wildlife over time, focusing on the 3-15 years post-harvest time period. We utilized the DNR monitoring data for our initial site selection processes (MNDNR 2016). The sites were selected via a random-stratified design to ensure sites were balanced by age since harvest and leave tree configuration across northern Minnesota. We focused on sites that had aspen as the dominate cover type pre-harvest and that were 20 acres to 40 acres in size (average

harvest size in Minnesota; MNDNR 2016)). For the site selection process we initially used the categorical designation from the MNDNR (clumped or scattered); however, we realized that this was not an accurate representation of tree retention and instead developed a variety of metrics to quantify tree retention in a stand to assess wildlife responses. We included a total of 69 forest stands in the observational portion of the study (Figure 1.6a).

We used a variety of data sources and methods including vegetation surveys, LiDAR, historical Google Earth imagery, NLCD, and Most Recent Fast Disturbance (MRFD) maps created by Vogeler et al. (2019) to calculate a total of 117 variables that quantify habitat characteristics of the 69 forest stands (sites) surveyed in this study. Forty-five stand-level variables were calculated at four scales (total stand, within-stand, core area, edge and point count locations; Figure 1.6b). Seventy-two variables were calculated at the landscape-level at three spatial scales (100 m, 500 m, and 1000 m buffers around each stand; Figure 1.6b). The stand-level variables were used to quantify features of the stand and tree retention within the stand including characteristics such as area, perimeter, age, canopy structure, proportion of retained trees, proportion of tree retention in scatter and clumped configurations, size of clumps, and density of clumps. The landscape-level variables characterized cover type composition at each buffer (e.g. development, agriculture, open water) and quantified the area impacted by disturbance (e.g. harvest) in each buffer. These metrics allowed us to develop models to assess community level and species-specific responses to tree retention.

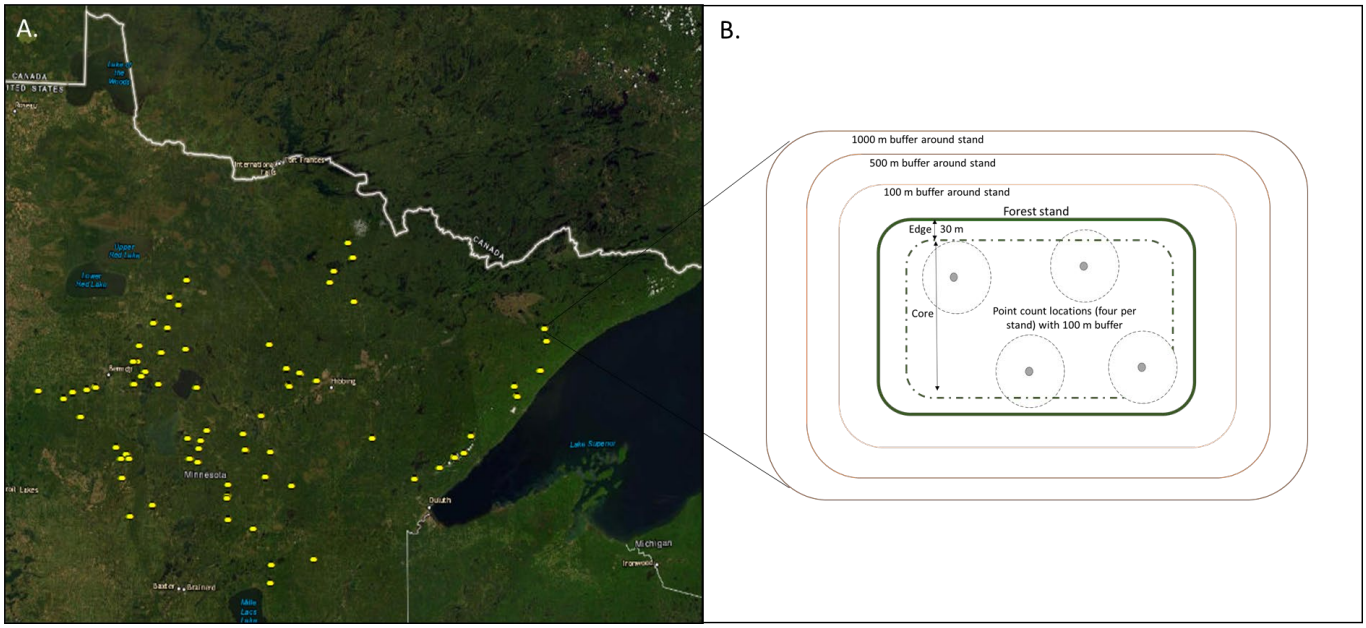

Figure 1.6. A.) Sixty-nine forest stands surveyed for the observational portion of the study, B.) Schematic of spatial scales used to quantify characteristics of forest stands.

The average age of stands surveyed was 8.5 years post-harvest and the average stand size was 28.6 acres. All of the stands included in the observational portion of the study had some tree retention; however not all stands met the MFRC tree retention guidelines. Twenty-one (30%) stands did not meet the minimum guidelines of having either 6-12 scattered trees per acres or 5% of harvest area in 0.25 acre minimum clumps. The majority of stands (65%) had a mixture of both clumped and scattered tree retention; all stands had scattered tree retention while 35% of the stands did not have any clumped tree retention. Overall the average estimated scattered leave tree density was approximately 10 trees per acre, but this was highly variable and ranged from 0 trees per acre to 41 trees per acre (Table 1.1). The median scattered tree density was 7 and was closer to the lower end of MFRC tree retention guidelines (Table 1.1). The average size of clumps was 0.8 acres, but was highly variable across stands, the largest retained clump was approximately 3 acres, and the median size was 0.6 acres which was well above the required size specified by MFRC guidelines.

Table 1.1. Summary statistics of 69 forest stands included in observational portion of the study.					
Variable description	**Mean**	**Std dev.**	**Median**	**Max. value**	**Min. value**
Proportion of total leave tree area from clumps (using MFRC definition of >0.25 acres; 1 = all clumped, 0 = all scattered)	0.32	0.29	0.31	0.95	0.00
Estimated scattered leave tree density (trees per acre) based on total stand area and estimated number of scattered leave trees	9.62	8.09	6.65	41.15	0.27
Density of clumps (using MFRC definition of > 0.25 acres) in clumps per acre based on number of clumps	0.07	0.08	0.04	0.35	0.00
Average size of clumps (using MFRC definition of > 0.25 acres)	0.80	0.54	0.64	3.14	0.25
Proportion of stand in retained scattered leave trees	0.07	0.06	0.05	0.31	0.00
Proportion of stand in retained clumped leave trees (using MFRC definition of > 0.25 acres)	0.05	0.07	0.03	0.36	0.00
Proportion of stand in retained leave trees -- both scattered and clumped configuration	0.12	0.11	0.09	0.47	0.00

Literature cited in this section:

- Kurth, V.J., J.B. Bradford, R.A. Slesak, and A.W. D'Amato. 2014. Initial soil respiration response to biomass harvesting and green-tree retention in aspen-dominated forests of the Great Lakes region. Forest Ecology and Management 328:342-352.
- Minnesota Department of Natural Resources (MNDNR). 2016. Minnesota's forest resources 2015. Saint Paul, MN. Available at http://files.dnr.state.mn.us/forestry/um/forest-resources-report-2015.pdf
- Minnesota Forest Resources Council (MFRC). 2014. Minnesota's forest management guidelines: Quick reference field guide. Saint Paul, MN. 83 p.
- Vogeler, J.C., R. A. Slesak, M. J. Falkowski. 2019. Most recent fast forest disturbances in Minnesota. Minnesota Geospatial Commons, https://gisdata.mn.gov/dataset/env-fast-forest-disturbances. [Last accessed 8/1/2019].

ACTIVITY 2: Quantify effects of leave tree configurations on bird, small mammal, and amphibian communities.
Description:

We will measure bird, small mammal, and amphibian diversity by conducting systematic counts at 60 harvest sites during the late spring and summer for 2 field seasons. Funding for this project will be used to measure bird, mammal, and herptile diversity at harvest sites. We will use a variety of wildlife survey techniques and technologies depending on site specific characteristics to obtain comprehensive information about wildlife communities at harvest sites. Avian survey techniques include point counts and digital audio recorders. Track stations, and camera traps will be used to survey mammals. Survey methods for herptiles include digital audio recorders and surveys of coarse woody debris. Together these methods will provide a comprehensive estimate of wildlife biodiversity in leave tree sites.

Wildlife survey methodology overview:

1. Point counts: Breeding birds
2. Digital Audio Recorders: Breeding birds and frogs
3. Camera traps: Mammals
4. Track plates: Mammals
5. Coarse woody debris surveys: Herptiles

The expected outcome of wildlife surveys will be to quantify presence/ absence and relative abundance of birds, mammals, and herptiles. Spatial pattern metrics of leave trees (Activity 1), harvest size, and time since harvest

will be related to field data. The deliverable from this activity will be the synthesis of these data to create a summary report on the effects of leave tree guideline implementation on biodiversity. These recommendations will be separate for each taxa (birds, mammals, and herptiles) because it is possible that there will be species-specific responses within each taxa. These analyses will allow us to assess the impact of tree retention levels and harvest size on the long-term abundance and diversity of Minnesota's wildlife. Findings will be presented to the Minnesota Forest Resources Council and recommendations will be made for modifications to the Forest Management Guidelines.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 140,850
Amount Spent: $ 140,850
Balance: $ 0

Outcome	Completion Date
1. Quantify bird, small mammal, and amphibian abundance and diversity at 60 research sites.	September 2018
2. Evaluate effects of leave tree configurations on species abundance and diversity.	April 2019
3. Develop recommendations and present findings to the Minnesota Forest Resources Council.	June 2019

Activity Status as of January 1, 2017:
Limited work has been completed associated with this activity other than discussion of field protocols that will be used for this portion of the project.

Activity Status as of July 1, 2017:
In May 2017, we deployed digital audio recorders (DARs) at 15 sites to record amphibian calls and American Woodcock and Ruffed Grouse activity. The data collected from the DARs in spring 2017 will be used to develop methodology for data collection at the remaining sites in 2018.

In June 2017, we surveyed 56 harvested stands across MN to assess breeding bird occupancy and abundance (Figure 2.1). However, we may need to exclude several stands from our final analysis due to differences in forest composition and harvest size. Surveys were also conducted at the experimental harvest sites in four study areas in St. Louis County, a total of 40 sites (Figure 1.2). Each stand survey consisted of four point count locations (Figure 2.2). This survey design allowed us to assess bird communities within the stands, spatial distribution of breeding birds in relation to tree retention, and account for differences in detection between stands. Point counts were conducted by trained observers from approximately 0.5 h before to 4 h after sunrise on days with little wind (< 15 km hr−1) and little or no precipitation. All birds heard or seen from the site were recorded, and distance was estimated as 0–25 m, 25–50 m, 50–100 m,>100 m. Data will be entered and preliminary analysis will be conducted fall 2017.

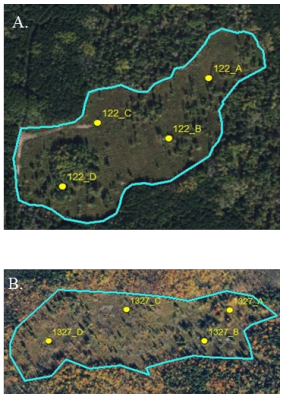

Figure 2.2. Representative examples of retained tree configurations, A.) clumped and B.) scattered. Four point count locations were surveyed in each stand to assess bird communities within the stand and the spatial distribution of birds.

Activity Status as of January 1, 2018:

Breeding Bird Surveys

A total of 2,065 individual birds and 65 species were detected during leave tree point counts in 2017. The most commonly detected bird was Chestnut-sided Warbler (407), followed by American Redstart (180), Golden-winged Warbler (167), Nashville Warbler (166), and Veery (123). Preliminary results suggest that diversity was higher in clumped and scattered trees compared to clearcut stands (Figure 2.3).

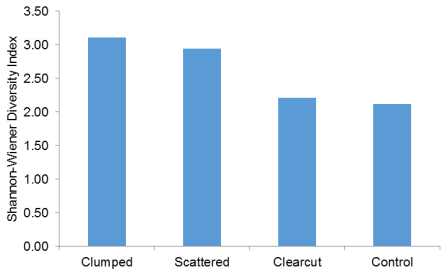

Figure 2.3. Summary of bird data Shannon-Wiener diversity index by treatment type from breeding bird surveys conducted June 2017.

Small mammal activity

We conducted preliminary surveys to assess mammal activity using camera traps and track plates; however we were unable to collect high quality data. Therefore, we decided to use small mammal traps to obtain mammal activity in harvested sites. In September 2017, we conducted our first round of small mammal trapping in four experimental study areas in St. Louis County, Minnesota (Figure 1.2). The University of Minnesota's Institutional Animal Care and Use Committee (IACUC) approved the protocol "Evaluation of Tree Retention Guidelines Pertaining to Small Mammals" (Protocol ID: 1709-35104A) on September 21, 2017.

Small mammals were trapped from 1 October to 7 October 2017. We used Sherman folding traps (3 x 3.5 x 9 " model LFATDG) baited with peanut butter dipped in oats, we also included a chunk of potato as a water source and cotton balls for bedding. A 2x5 (10 traps) transect array of traps was used at each plot, traps were spaced at intervals of 15 m, with the center of the left transect being placed at the center of the plot. To maximize capture probabilities, traps were placed opportunistically near the best available microhabitat (e.g. along logs, near

stumps). Traps were set in the late afternoon of the first day, run for two consecutive nights and pulled the morning after. Traps were checked twice daily, re-baited, and cotton and potatoes were replaced as needed. Small mammals were identified, weighed, marked with ear tags; small mammals were identified to species with the exception of *Peromyscus* species. Animals were tagged with a single ear tag (Monel #1005-1, National Band and Tag Company) or marked with a black marker (shrews, meadow voles). Larger mammals (flying squirrels, short-tailed weasel) were identified then quickly released. Notes were made for traps that had either no activity (trap was tripped, but no small mammal activity) or no capture (small mammal activity, bait chewed on, etc.). Small mammals were trapped in favorable weather conditions (e.g. little to no rain).

Results

A total of 149 individuals of 6 species were caught over 800 trap nights and 400 trap days. Red-backed Voles made up 58% (86 individuals) of the total captures, followed by *Peromyscus* sp. (24%, 36 individuals) and short-tailed shrews (13%, 20 individuals). Three other species had six or fewer individuals: Eastern Chipmunk (4), Short-tailed weasel (2) and Red Squirrel (1).

The total number of individuals was highest in clumped sites, which accounted for 47% of all individuals, followed by scattered sites (27%), clearcut sites (17%) then control sites (13%). Clumped sites had the highest species richness 2.25 species per site, followed by scattered sites (1.83 species per site), control sites (1.75 species per site) then clearcuts (1.25 species per site). While it is too early in the project to formally analyze the data, Figure 3 summarizes 2016 small mammal abundance by treatment type (Figure 3a) and species richness by treatment type (Figure 3b).

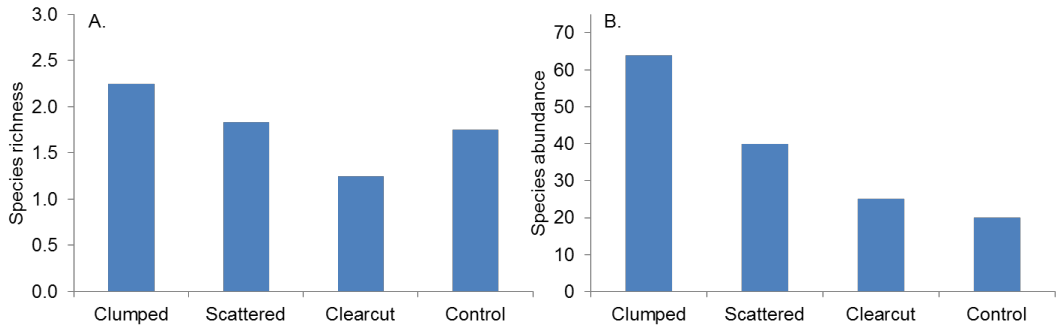

Figure 2.3. Summary of small mammal A.) Species richness and B.) Species abundance by treatment type from Fall 2017 small mammal trapping surveys.

Activity Status as of July 1, 2018:

<u>Spring-Summer 2018:</u>

Digital Audio Recorders: DARs were deployed in 40 leave tree stands in May 2018 to detect amphibian calls and American Woodcock, Wilson's Snipe, and Ruffed Grouse activity. DARs data will be analyzed fall 2018.

Breeding bird surveys: We completed the second year of breeding bird surveys for 60 leave tree sites and four experimental study areas in June 2018. Data will be entered, quality checked, and summarized fall 2018.

Activity Status as of January 1, 2019:

We have completed all wildlife surveys for this project. We have identified 87 bird species and counted over 6,500 individual birds during the 2017 and 2018 breeding season. The most abundant bird species identified in our study sites are Chestnut-sided Warbler, American Redstart, Veery, and Nashville Warbler.

A total of 155 individuals of seven small mammal species were caught over 800 trap nights and 400 trap days. Red-backed Voles made up 65% (101 individuals) of the total captures, followed by *Peromyscus* sp. (23%, 36 individuals) and short-tailed shrews (13%, 20 individuals). Four other species had five or fewer individuals: Eastern chipmunk (5), flying squirrel (4), short-tailed shrew (3), meadow voles (2), and red squirrel (2). We also had two shrews that we were unable to identify at the species level.

We are currently analyzing the data to assess the impacts of tree retention configuration on wildlife abundance and diversity. We are analyzing the data from the experimental sites and the 60 additional sites separately but using similar modeling approaches for each data set. For the experimental sites, we are using generalized linear mixed models to assess the differences in wildlife communities between treatments (clumped, scattered, clearcut, and control). We are also using generalized linear mixed models to determine the relationship between species diversity and abundance for the 60 additional sites. These sites show a gradient of tree retention and "clumpiness" of retained trees across all sites and ages, and our objective is to focus on the response in species diversity and interaction between retention and stand age. This approach will allow us to determine the relationships between tree retention and diversity and how these relationships change as stands mature.

Final Report Summary:
We are in the process of writing two manuscripts that will be submitted to peer-review journals, the results of the analyses are summarized below.

*Note on herptile data***.** We used digital audio recorders and coarse woody debris surveys to assess herptile presence and absence in experimental stands and in a subset of the observational study sites. We detected five amphibian species in this study using the digital audio recorders; American toad (*Anaxyrus americanus*), gray treefrog (*Hyla versicolor*), northern leopard frog (*Lithobates pipiens*), wood frog (*Lithobates sylvaticus*), and northern spring peeper (*Pseudacris crucifer*). The presence / absence of breeding frog species was driven by occurrence of wetlands in the stands, but only 35% of our stands contained either ephemeral or permanent wetlands. Due to a lack of data across sites we were not able to assess the impacts of tree retention on herptiles communities. Additional studies that specifically focus on forest stands with either ephemeral or permanent wetlands are needed to assess the impacts of tree retention on herptiles.

Experimental design.
We used the small mammal and bird community data collected at the experimental leave tree sites to evaluate the research question: **Do current leave tree guidelines benefit wildlife?** Bird and small mammal communities were summarized using two metrics: total abundance (total number of unique individuals in each treatment site) and species diversity (calculated using the Shannon–Wiener index of diversity). A generalized linear mixed-effects model was used to assess the impact of leave tree treatment type and biomass retention on total abundance and species diversity for breeding bird and small mammal communities.

Small mammal community results. Treatment was the only significant predictor for small mammal response variables. The models show that small mammal species diversity was significantly higher in clumped treatments compared with clear-cut treatments (Figure 2.4a). Small mammal species diversity in scattered treatments was not significantly different from either the clumped or clear-cut treatments (Figure 2.4a). Similarly, the total abundance of small mammals was significantly lower in clear-cut stands compared with clumped sites and the total number of individuals in scattered treatments was not significantly different from either treatment (Figure 2.4b). These results provide compelling evidence that clumped tree retention is the optimal configuration for small mammal diversity and abundance.

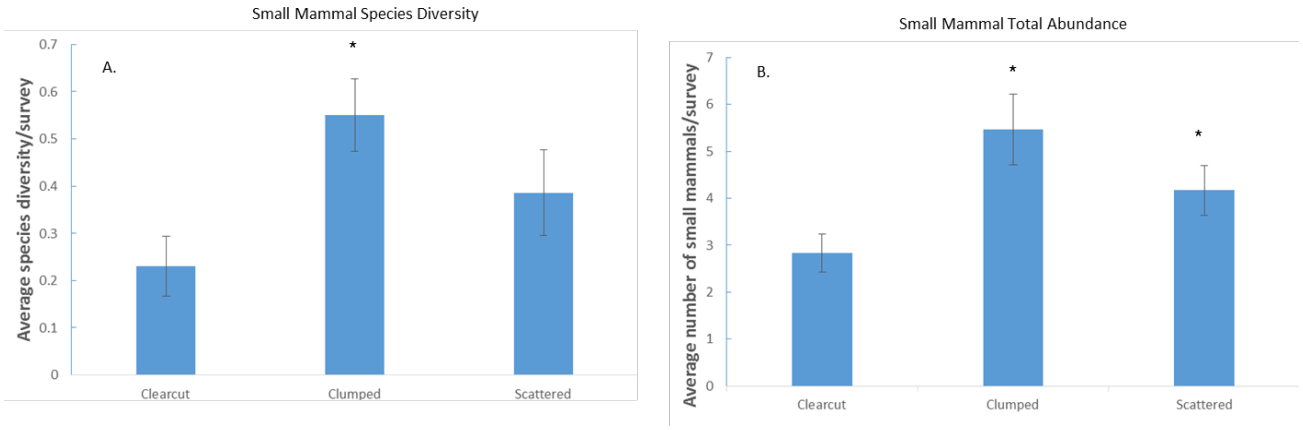

Figure 2.4. Summary of small mammal A.) species diversity and B.) total abundance by treatment type from 2017-2018 fall small mammal trapping surveys. * indicate significant results based on results of generalized linear mixed-effects model with Tukey's post-hoc adjustment.

Bird community results. Treatment was the only significant predictor for bird community response variables. Pairwise comparisons between treatment effects show that species diversity was significantly greater in clumped compared with clear-cut treatments and between scattered and clear-cut treatments, but not between scattered and clumped treatments (Figure 2.5a). Total abundance was significantly greater in scattered compared with clear-cut treatments, but not between clumped and clear-cut treatments, and there was not a significant difference between scattered and clumped treatments (Figure 2.5b). Overall, these results indicated that clear-cut stands, even seven years post-harvest, provided fewer benefits to breeding birds compared with the clumped or scattered treatments.

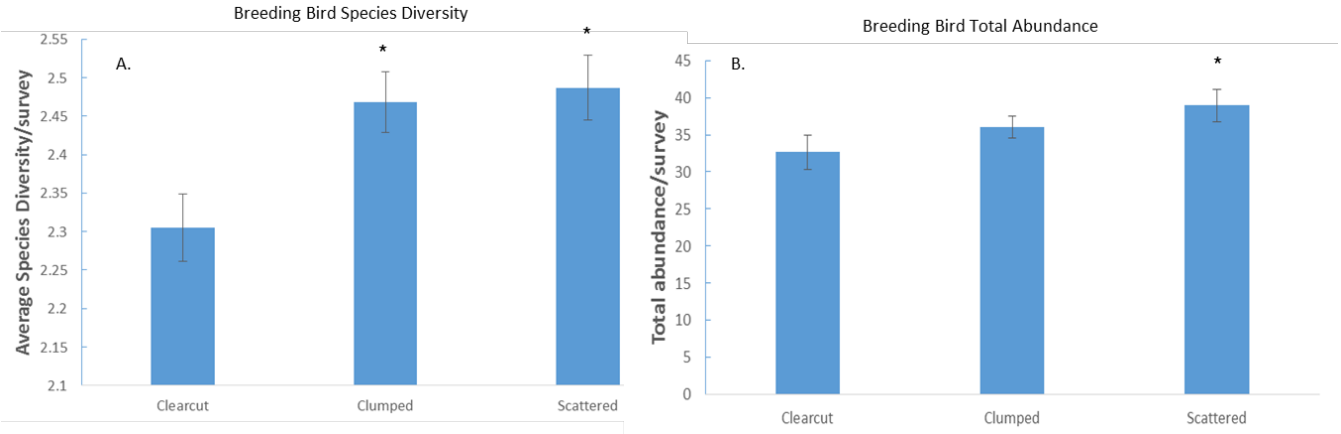

Figure 2.5. Summary of breeding bird A.) species diversity and B.) total abundance by treatment type from 2017-2018 summer breeding bird surveys. * indicates significance based on results of generalized linear mixed-effects models with Tukey's post-hoc adjustments.

Conclusions. The current MFRC guidelines are beneficial for wildlife and increase the diversity and total abundance of bird and wildlife species that use forest stands post-harvest.

Observational design.

We used the bird data collected at the 69 observational leave tree sites to evaluate the research question: **How does tree retention and configuration influence wildlife?** Specifically, we were interested in the relationships between tree retention (density and configuration) and its impact on bird diversity over time (stand age). We used two modeling approaches to compare bird community composition (total abundance and diversity) between clumped and scattered sites. We used generalized linear mixed-effects models to assess the influence

of stand variables on total abundance and species diversity. We also used joint species distribution models to assess the influence of tree retention levels and configuration on relative abundance of individual species.

Stand age. Our results show that bird diversity and total abundance was highest five to eight years post-harvest and declined slightly up to 19 years post-harvest. Note that the oldest stand we sampled were 19 years. Stands that had clumped as the predominate configuration maintained total abundance and diversity as the stand aged whereas stands with scattered tree retention showed a general decrease in both total abundance and species diversity over time (Figure 2.6). Thirty-four species had adequate sample size to assess species-specific responses to stand age using joint species distribution models. The results indicated that eight bird species (Chestnut-sided Warbler, Golden-winged Warbler, Mourning Warbler, Gray Catbird, Indigo Bunting, Alder Flycatcher, American Goldfinch, and Song Sparrow) significantly decreased in relative abundance with stand age; Ovenbird was the only species that significantly increased with stand age (Figure 2.7).

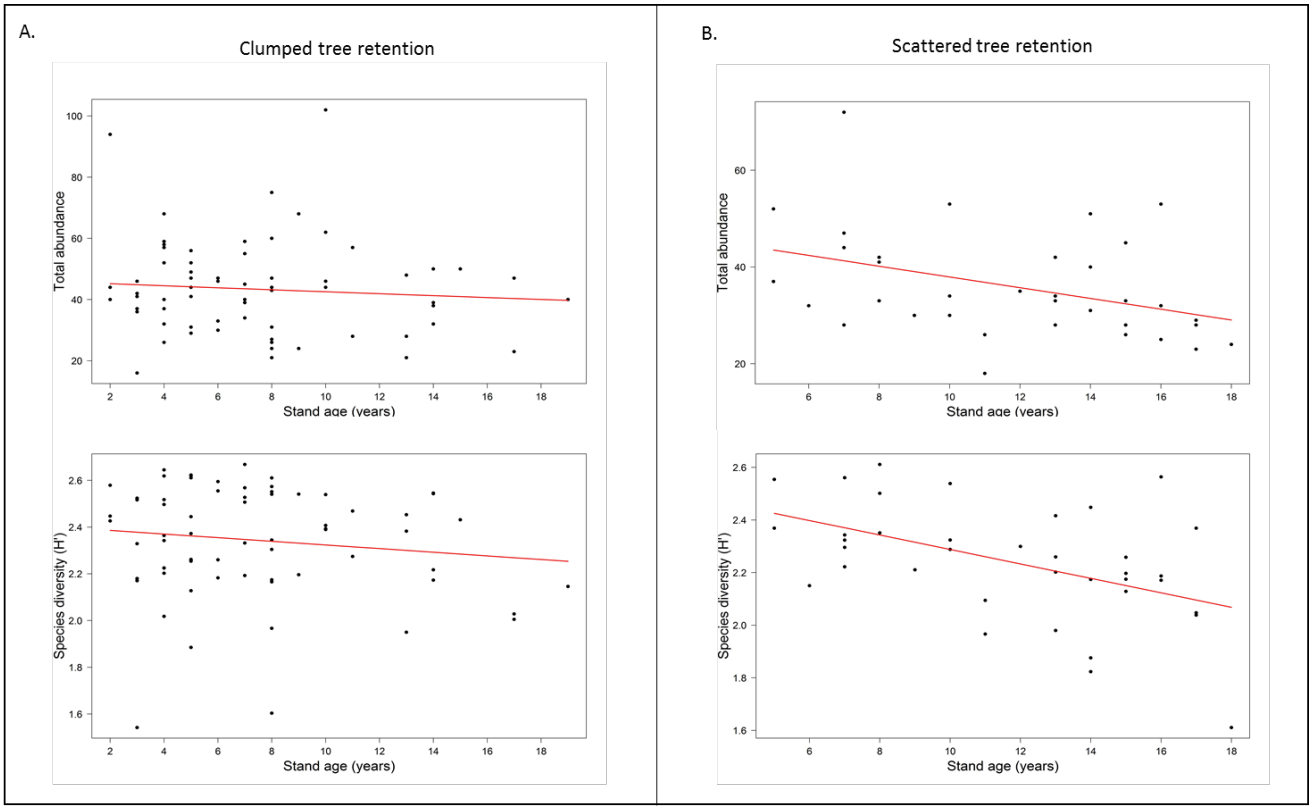

Figure 2.6. Relationship between total abundance and species diversity of breeding birds over time in stands with A.) predominately clumped tree retention and B.) predominately scattered tree retention.

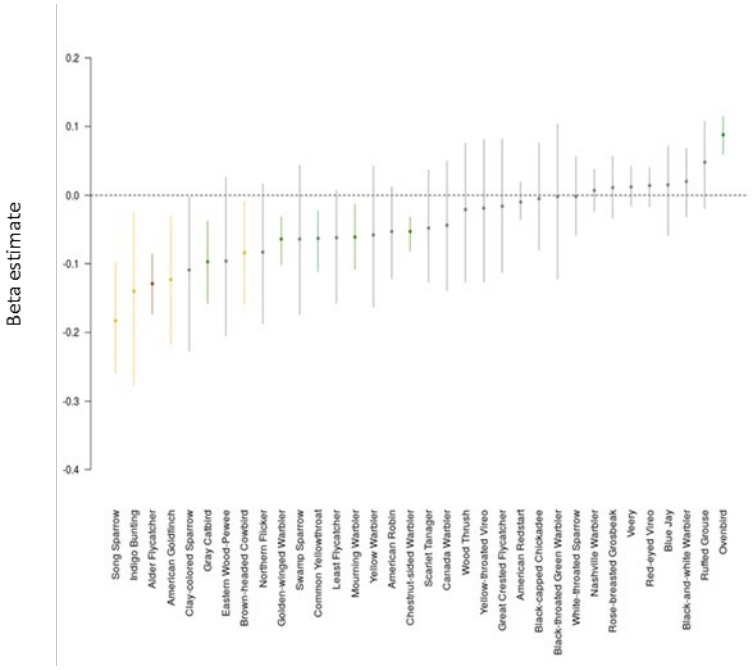

Figure 2.7. Results from joint species distribution models developed to assess the relationship between species relative abundance and stand age. Beta estimates are plotted with associated confidence intervals; confidence intervals that do not cross the dotted line indicate significant results. For instance, species results that are completely below the line indicate they prefer areas of younger forests, while those above prefer older forests.

Density of tree retention. Overall, higher levels of tree retention in stands increased the relative abundance of nine species (Chestnut-sided warbler, American Redstart, Ovenbird, Alder Flycatcher, Mourning Warbler, Least Flycatcher, Wood Thrush, Indigo bunting, Canada Warbler; Figure 2.8). However, high levels of tree retention negatively impacted relative abundance of five species (Veery, Nashville Warbler, Golden-winged Warbler, Gray Catbird, and Yellow Warbler; Figure 2.8). The magnitude of response to tree retention was species-specific (Figure 2.8).

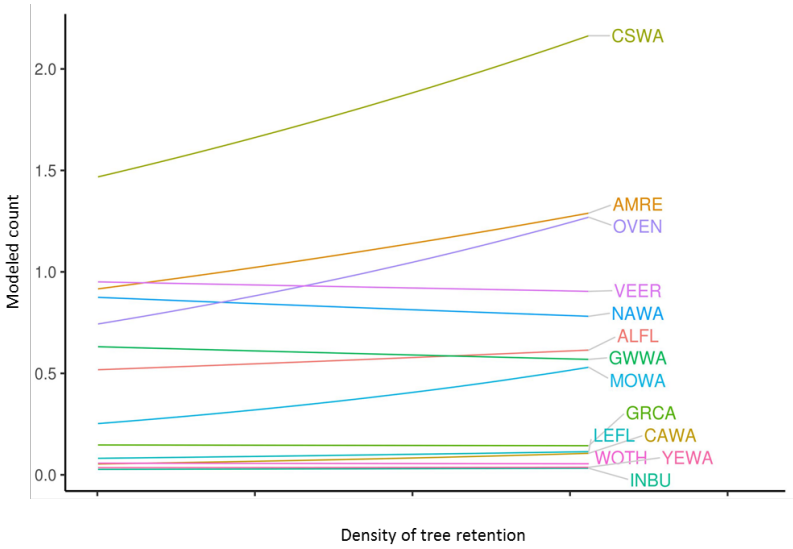

Figure 2.8. Results from joint species distribution models developed to assess the relationship between species relative abundance and density of tree retention (proportion of tree retention / total harvest area). Slope of the

lines are based on beta estimates from final models, only species with significant results are included in the figure.

Configuration and density of tree retention. The relative abundances of 22 species were positively associated with higher levels of clump density (Figure 2.9a); however, scattered leave tree density did not significantly impact the relative density of any species (Figure 2.9b). These results suggest that species responded favorably to trees retained in clumped or aggregated configurations more favorably than scattered trees.

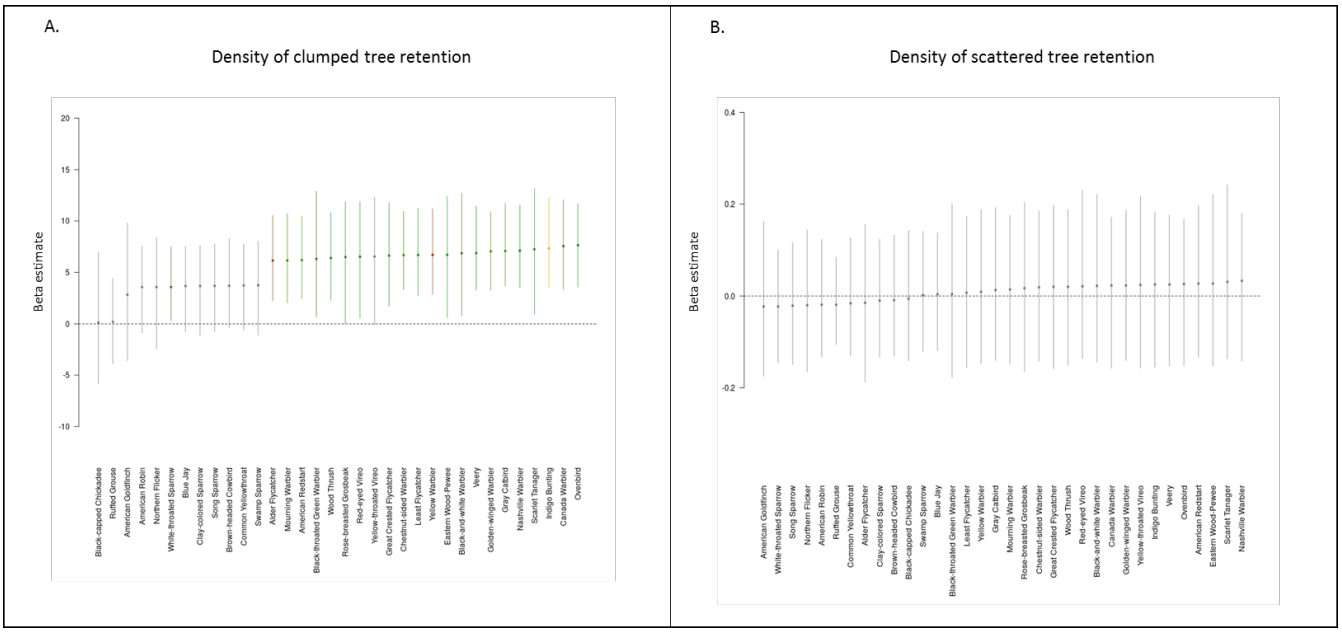

Figure 2.9. Results from joint species distribution models developed to assess the relationship between species relative abundance and A.) density of clumped tree retention, and B.) density of scattered tree retention. Beta estimates are plotted with associated confidence intervals; confidence intervals that do not cross the dotted line indicate significant results. Species above line preferred stands with clumped or scattered tree retention.

Conclusions. Overall, our results show that there is a positive relationship between tree retention and bird diversity. Logged forest stands that leave trees in a clumped fashion maintain higher bird diversity over time and significantly increase the relative abundance of 22 breeding species. We recommend that the MFRC continue to promote clumped or a combination of clumped and scattered retention of trees.

V. DISSEMINATION:

Description:
Project results will be summarized and presented to the MFRC for evaluation, and a summary report made available on NRRI's website and on the MFRC website. In his role as Site-level Program Manager at the MFRC, R. Slesak will use the information to either validate the existing leave tree guidelines, or propose alternative guidelines that mitigate impacts on forest bird, herptile and mammal species.

Ultimately, the information will be transferred to loggers and resource managers during guideline training sessions, as these groups are the primary users of Minnesota's Forest Management Guidelines. In addition to the above, manuscripts detailing project results will be written and submitted for publication in peer-reviewed journals.

Status as of January 1, 2017:
Materials are not ready to disseminate.

Status as of July 1, 2017:
Materials are not ready to disseminate.

Status as of January 1, 2018:
Materials are not ready to disseminate.

Status as of July 1, 2018:
Materials are not ready to widely disseminate however, we have presented preliminary results at the following workshops and conferences:

- Forestry and Wildlife Research Review, Cloquet Forestry Center, January 11, 2018.
- The Minnesota Chapter of The Wildlife Society Meeting, St. Cloud Minnesota, February 12-14, 2018.
- Charting the Future for Northern Forest Birds: Takin it to the Tweets workshop in Ashland, WI, April 16-17, 2018.
- Forestry for Lake States Birds, Long Lake Conservation Center, June 22-23, 2018.

Status as of January 1, 2019:

- We will be presenting the results of this project at the Forestry and Wildlife Research Review, Cloquet Forestry Center, January 10, 2019 and The Minnesota Chapter of The Wildlife Society Meeting, Duluth Minnesota, February 19-21, 2019.

Final Report Summary:

- We have already disseminated our findings to practitioners at a number of workshops and training sessions with positive feedback from attendees. These efforts will continue in cooperation with the MFRC and its partners.
- The results of this project were featured in NRRI's newsletter and can be found here: https://www.nrri.umn.edu/natural-resources-research-institute/news/tree-retention
- The results of this report were presented to the MFRC on March 14th, the MFRC has indicated that it will use our findings to evaluate the suitability of existing leave tree guidelines during the next guideline revision, which is tentatively planned to being in 2020. Their use of our work represents a direct link between research and practical real-world applications.
- We are in the process of completing two peer-reviewed manuscripts for this project and plan to have them submitted by the end of the year.

VI. PROJECT BUDGET SUMMARY:
A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 217,674	1 project manager at 0.3% FTE each year for 3 years ($2,000); 2 co-investigators, 1 at 27.3% FTE each year for 3 years ($53,726), and 1 at 30% FTE each year for 3 years ($51,200); 1 research associate at 10% FTE each year for 3 years ($33,700); 1 post-doctoral researcher at 50% FTE for year 1 ($31,100); 2 field technicians at 20% FTE each year for 3 years ($35,348); 1

		undergraduate research assistant at 25% FTE for year 2 ($6,900); 1 administrative support staff at 2% FTE each year for 3 years ($3,700).
Equipment/Tools/Supplies:	$ 1,250	Sherman traps
Travel Expenses in MN:	$ 13,076	Mileage ($9,807); lodging ($3,269)
TOTAL ENRTF BUDGET:	**$ 232,000**	

Explanation of Use of Classified Staff: N/A

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

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

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

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
State			
Gerald Niemi, project manager (cash support)	As needed	-	If awarded, NRRI will contribute time and effort as needed for successful completion of the project without requesting further funds from LCCMR.
Foregone F&A funding of 52% TDC	$ 120,640	$ 120,640	Indirect costs on personnel, travel, and supplies related to work on the sponsored project
Robert Slesak, MN Forest Resources Council (in-kind support)	$ 35,000	$ 35,000	Salary and fringe of 0.1 FTE each year for 3 years for effort spent on project activities.
TOTAL OTHER FUNDS:	**$ 155,640**	**$155,640**	

VII. PROJECT STRATEGY:

A. Project Partners: The project team includes Dr. Gerald Niemi, Dr. Alexis Grinde, and Annie Bracey and Ed Zlonis from the Natural Resources Research Institute, Dr. Michael Falkowski at the University of Minnesota, and Dr. Rob Slesak from the MN Forest Resources Council. Cooperators will include the DNR Division of Forestry and Division of Fish & Wildlife who we will work closely with to incorporate the findings into operational practice on state lands.

B. Project Impact and Long-term Strategy:

This proposal is a part of a larger strategy to assess the effectiveness of Minnesota's Forest Management Guidelines. Findings will be incorporated into Minnesota's Forest Management Guidelines, and recommendations widely implemented across the state by DNR, US Forest Service, Counties, industry, and other forestry partners.

C. Funding History: N/A

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A

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

X. RESEARCH ADDENDUM: N/A

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than January 1, 2017; July 1, 2017; January 1, 2018; July 1, 2018; and January 1, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

Environment and Natural Resources Trust Fund
M.L. 2016 Project Budget

Project Title: Evaluation of Tree Retention Guidelines Pertaining to Wildlife
Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 03p
Project Manager: Gerald Niemi
Organization: Natural Resources Research Institute, University of Minnesota Duluth
M.L. 2016 ENRTF Appropriation: $232,000
Project Length and Completion Date: 3 years, June 30, 2019
Date of Report: August 15, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	**Measure leave tree configuration and quantify habitat characteristics of 60 harvest sites with LiDAR**			**Quantify effects of leave tree configurations on bird, small mammal, and amphibian communities**				
Personnel (Wages and Benefits)	$91,150	$91,150	$0	$126,524	$126,524	$0	$217,674	$0
Gerald Niemi, Project Manager: $2,000 (66.3% salary, 33.7% benefits); 0.3% FTE each year for 3 years								
Alexis Grinde, Co-Investigator: $53,726 (82.4% salary, 17.6% benefits); ~27.3% FTE each year for 3 years								
Ed Zlonis, Co-Investigator: $51,200 (66.3% salary, 33.7% benefits); 30% FTE each year for 3 years								
Michael Falkowski, Research Associate: $33,700 (66.3% salary, 33.7% benefits); 10% FTE each year for 3 years								
1 Post-doctoral Reseacher: $31,100 (77.6% salary, 22.4% benefits); 50% FTE for year 1								
2 Field Technicians: $35,348 (92.1% salary, 7.9% benefits); 20% FTE each year for 3 years								
Undergraduate Research Assistant: $6,900 (100% salary, 0% benefits); 25% FTE for year 2								
Kim Rewinkel, Administrative support: $3,700 (72.6% salary, 27.4% benefits); 2% FTE each year for 3 years								
Equipment/Tools/Supplies								
50 Sherman traps ($25 each) for small mammal monitoring				$1,250	$1,250	$0	$1,250	$0
Travel expenses in Minnesota								
Travel for fieldwork, including mileage (75%) and lodging (25%) for researchers, field technicians, and graduate and undergraduate students. Mileage costs are associated with rental of a field vehicle through the University of Minnesota motorpool for four field sessions each year for 3 years. Travel reimbursement will follow University of Minnesota protocols.				$13,076	$13,076	$0	$13,076	$0
COLUMN TOTAL	**$91,150**	**$91,150**	**$0**	**$140,850**	**$140,850**	**$0**	**$232,000**	**$0**