M.L. 2015 Project Abstract
For the Period Ending June 30, 2018

PROJECT TITLE: Endangered Bats, White-Nose Syndrome, and Forest Habitat
PROJECT MANAGER: Richard Baker
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 03i

APPROPRIATION AMOUNT: $ 1,250,000
AMOUNT SPENT: $ 1,250,000
AMOUNT REMAINING: $ 0

Overall Project Outcome and Results

The Northern long-eared bat's (NLEB) listing as threatened under the federal Endangered Species Act prompted the DNR to undertake this project. The federal listing was in response to the impact of White Nose Syndrome (WNS) on bats throughout North America. WNS was detected in Minnesota in 2016, and NLEB hibernating in the Soudan mine subsequently declined drastically. The project first (Activity 1) compiled historic data to identify past distribution of NLEB. We next (Activity 2) deployed acoustic detectors throughout the forested region of Minnesota and found NLEB at over half of the detector sites. Bats most common in southern Minnesota were NLEB, big brown bat, red bat, little brown bat, and silver-haired bat. In northern Minnesota, NLEB, little brown bat, and silver-haired bat were most common.

In Activity 3, we used radiotelemetry to locate bat roost trees. We captured 1,202 bats, with little brown bat (37%), big brown bat (31%), and NLEB (17%) most common. Pregnant females were captured into the third week of July, with lactating females more common after the last week of June. Juveniles were captured from the 3rd week of June to the end of July. We tracked 83 female NLEB to 238 roost trees. Surprisingly, almost 80% of the time a roost tree was used for only 1 night before switching to a different roost tree, which meant females carried young to a different roost tree often. Maternity roost home range size for female NLEB was about 18 acres.

In Activity 4, we found that NLEB females roosted in 27 different tree species, with 90% of roosts in deciduous tree species and 10% in conifer species. Most roost trees were in upland forests. Aspen trees were used most in northern Minnesota, maple and aspen trees in central Minnesota, and oak in southern Minnesota. Female NLEB preferred roost trees surrounded by mature forest. Roost tree habitat in northern Minnesota is broadly distributed. In southern Minnesota, female NLEB selected a wider range of roost trees than in the north, probably reflecting the greater presence of agriculture and development. We mapped areas of Minnesota that should be suitable habitat for female NLEB while raising young, based on distribution of NLEB in Minnesota and forest characteristics.

Results of this project benefit Minnesota because we have identified roost tree habitat for NLEB that is critical for successful reproduction. We have identified when female NLEB are pregnant and lactating, and shown that young must be carried from one roost to another. The data collected in this project will enable development of management strategies to help recover the NLEB population, and can also be used for management of other bat species.

Project Results Use and Dissemination

Over the 3 years of this project we disseminated information to several outlets as listed in the project work plan. Site level reports and annual reports have already been shared with LCCMR and with Resource Management Agencies. Technical Reports, and additional peer-reviewed papers that will be written based on data collected in this project will be used in to develop future management actions for the Northern long-eared bat, and other bat species that could be listed in the future in response to White Nose Syndrome. NLEB roost tree locations have been entered into the DNR's Natural Heritage Information System. The results of this project are serving a critical role in the development of the Lake States Forest Bat Habitat Conservation Plan, a collaborative effort involving the states of Minnesota, Wisconsin, and Michigan that will provide the basis for bat conservation efforts in the three states. A full list of reports can be found in the final report.

Environment and Natural Resources Trust Fund (ENRTF) M.L. 2015 Work Plan Final Report

Date of Report: November 19, 2018

Final Report

Date of Work Plan Approval: June 11, 2015

Project Completion Date: June 30, 2018

PROJECT TITLE: Endangered Bats, White-Nose Syndrome, and Forest Habitat

Project Manager: Richard Baker

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Location: Statewide

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$1,250,000**
	Amount Spent:	**$1,250,000**
	Balance:	**$0**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03i

Appropriation Language:
$1,250,000 the first year is from the trust fund to the commissioner of natural resources in cooperation with the University of Minnesota and the U.S. Forest Service to survey and radio-track endangered bats to define and understand summer forest habitat use in order to minimize forestry impacts and mitigate white-nose syndrome disease impacts. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Endangered Bats, White-Nose Syndrome, and Forest Habitat

II. PROJECT STATEMENT:

The Minnesota Department of Natural Resources proposes a partnership with the University of Minnesota and the U.S. Forest Service to learn how to best protect bat summer habitat in Minnesota's forests. This project will build upon a pilot project being jointly implemented in 2014 by the DNR, Superior National Forest (SNF), and Camp Ripley Training Center.

Background and Significance

- Bats are a critical component of Minnesota's ecosystems. A single bat may eat 1,000 insects per hour, and the state's half million bats provide many millions of dollars in pest control each year.
- Seven species of bats are found in Minnesota. Four of these bat species (northern long-eared bat, tricolored bat, little brown bat, and big brown bat) hibernate in caves during the winter, and disperse widely across the state in spring, summer, and fall. These four cave-hibernating bats are all Species of Special Concern in Minnesota.
- Many cave bats use trees for roosting and raising young. Very little is known about this summer habitat. In October 2013, the U.S. Fish and Wildlife Service (USFWS) proposed to list the northern long-eared bat under the federal Endangered Species Act, largely due to the impact of the disease, white-nose syndrome. The Northern long-eared bat was listed on April 2, 2015. The state's three other cave bats are also susceptible to this disease, and may be proposed for listing in the near future.
- While the disease has yet to be observed in Minnesota, the fungus associated with it was detected on bats at Mystery Cave State Park and Soudan Underground Mine State Park in 2013. In the northeastern US, the disease has reduced bat populations by up to 99% over the past decade. Similar declines are expected in Minnesota.
- Bats reproduce very slowly, and successful reproduction will be critical to the four species' survival in the face of white-nosed syndrome and wind turbine fatalities. With the northern long-eared bat listing, the USFWS imposed restrictions on tree cutting between April 1 and September 30. Forest management activities are restricted within 0.25 miles of known hibernacula or maternity roosts, and known roost trees may not be cut. This broad prohibition, and potentially others in the future, will have an enormous impact on the management of Minnesota's 17.4 million acres of forest.
- The listing of Minnesota's cave bats will also affect the future of Minnesota's growing wind energy industry. Wind power is a sustainable energy resource, but fatalities at wind turbines are also having a significant impact on the state's bat populations.
- Collecting acoustic data is an efficient and cost-effective way to survey other bat species in an area, and could provide information on other species of bats in the future.
- Gathering and analyzing existing sonar data and conducting acoustic surveys sequentially across the forested area of Minnesota over three years will create a baseline to evaluate bat presence. If white-nose syndrome appears in Minnesota and begins to affect the bat populations, these data could be used for research and monitoring of bat populations statewide. It is very likely that white-nose syndrome will begin to cause bat mortalities in Minnesota during the timeline of this project, and the data we gather could help quantify the impacts of this disease on all Minnesota bats.
- The information collected about roosts, colony trees, and stands will be used by the DNR, U.S. Forest Service and possibly USFWS to develop forest management recommendations for protecting bat summer habitat in Minnesota.

Objectives

- The project will use available data, surveys, and the latest radio-tracking methods to improve our knowledge of northern long-eared bat summer forest habitat use.
- The project will identify the most critical periods and most critical habitat for bat reproduction in order to more effectively focus any restrictions on tree removal.
- Data will also be collected on the state's three other cave-dwelling bat species for future use as needed.

Activities and Methods

- Review, analyze, and summarize existing unpublished data from acoustic detectors to identify gaps in knowledge about the distribution of bats in Minnesota.
- Use acoustic detectors in areas where acoustic surveys have not been done before.
- Deploy transmitters on northern long-eared bat (NLEB) in the maternity season to identify roost trees.
- Characterize the roost trees and the forest matrix within which NLEB raise young, and use this data to develop appropriate management responses.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2016:
We have identified potential sources of bat acoustic data and started compiling this data in a central database. To date, we have compiled >22,000 call files from 104 sites across Minnesota. We have also started using Kaleidoscope Pro software to identify recorded bat calls. In 2015 we deployed acoustic detectors at 98 locations in ACTIVITY 2 and recorded >12,000 call files. With additional outside funding, we were able to conduct a pilot season of mist-netting and telemetry beginning in June 2015, conducting mist-netting at 39 sites in 6 counties, capturing 206 bats, and deploying transmitters on 24 female northern long-eared bats. We identified 71 unique roost trees of at least 15 species. We conducted emergence counts on 51 roost trees and observed an average of 21.5 bats emerging (range 1-79).

We collected data at 70 roost trees and 80 random trees in 2015. Data collected included tree species, decay class, diameter at breast height (dbh), tree height, roost type, canopy cover, and stand basal area. Roosts were most often in trees with some signs of decline or decay, although some roosts were in healthy, live trees. The average roost tree diameter of 34 cm (13") was slightly larger than the 29 cm (11") average diameter of random trees. Roosts were located in trees with diameters as small as 16 cm (6"). Tree height, canopy cover, and stand basal area was similar at roost trees when compared to random trees.

Amendment Request (February 5, 2016):
The project budget includes $75,000 that is being retained by the DNR to support participation in Activities 1, 2, and 3 of the project. In the original Work Plan, this entire amount was committed to “Personnel (Wages and Benefits).” However, as the project partners have discussed how to best accomplish the project goals, it has become apparent that the most efficient use of DNR funds will be for a portion of them to be re-allocated to “Equipment/Tools/Supplies” and “Travel Expenses in Minnesota” so that the DNR’s role can cover all expenses associated with assisting with the field component of the project. This reduction in Personnel expenses results in a $2,908 reduction in funds that must be spent on Direct Support Services. These funds have been re-allocated to the “Travel Expenses in Minnesota”($1,908) and “Other” ($1,000) categories. Finally, an incorrect allotment of a portion of the Direct Support Services into Activity 4 has also been eliminated, since DNR is not participating in Activity 4.

Amendment approved by LCCMR 2-10-2016

Project Status as of July 1, 2016:
We have requested acoustic data from various sources and have used Kaleidoscope Pro software and Sonobat 3 software to identify and organize acoustic files as they are received under Activity 1, and have created geospatial and database summaries of all acoustic data received. We purchased acoustic detectors in August

2015, and have deployed acoustic detectors at 145 locations in Activity 2. We have purchased supplies for a new mist-netting crew based out of NRRI, in addition to crews used last year by the MN DNR and USDA-Forest Service. All four mist-netting crews began mist-netting in early June, and so far have captured 446 bats at 36 sites, with MYSE captured at 25 sites. Radio-transmitters have been attached to 51 female northern long-eared bats, and radiotelemetry and emergence counts are in progress to locate and confirm maternity roost trees. So far, at least 125 maternity roost trees have been identified.

Project Status as of January 1, 2017:
During the 2016 field season we conducted acoustic surveys at 155 locations across the state. We also mist-netted at 62 sites and captured 640 bats. We tracked 42 adult female northern long-eared bats to 107 roosts and collected data the roost trees and nearby random trees. In addition, we have analyzed all of the acoustic data from 2015, and have begun analyzing acoustic data from 2016. This brings the total bats captured for the project (2015 & 2016 combined) to 846, with 66 female northern long-eared bats tracked to 187 roost trees.

In 2015 and 2016 combined, roost trees have been located in at least 22 species of trees with varying DBH and height. Decay stage also varies, but the majority of roosts have been located in declining or dead trees. Emergence surveys have counted as many as 79 bats using one roost. Bats with transmitters move roosts often, usually spending only 1-3 days per roost tree before moving to another tree. Consecutive roost trees are usually within 1000 m.

Project Status as of July 1, 2017:
We have summarized the data from existing bat acoustic surveys across the state, and finished analysis of all new acoustic data collected in 2016. Acoustic detectors have been deployed at 28 locations so far in 2017. All mist-netting crews began capturing bats in June, and as of June 30th have captured 192 bats including 22 MYSE. Capture rates have been much lower than in previous years, probably due to winter mortalities from WNS. Due to the lower capture rates, we have only been able to attach radio-transmitters to 14 female northern long-eared bats. Because of low capture rates for MYSE we have also begun to attach radio-transmitters to female and male little brown and big brown bats. To date 7 transmitters have been deployed on species other than northern long-eared bats. We have identified 42 new northern long-eared bat roost trees and 4 roosts of other bat species.

Project Status as of January 1, 2018:
Fieldwork for this season ended in Fall 2017, with the last acoustic data collected in October. Mist-netting ended in July. We deployed acoustic detectors at 70 locations in 2017. We captured 350 bats at 57 sites, and tracked 19 northern long-eared bats, 10 little brown bats, and eight big brown bats to their roosts. We identified 56 northern long-eared bat roost trees, 12 little brown bat roost trees, and 13 big brown bat roost trees. Northern long-eared bats roosted in at least 17 species of trees of varying diameter and decay stage.

We have continued to compile and summarize data collected for this project over the past three years. Almost 2TB of acoustic data have been collected. Analysis of 2017 acoustic data in the Kaleidoscope and Sonobat software programs is ongoing. In total, we have data on 237 roost trees used by female northern long-eared bats. We are also beginning to format our acoustic and capture data into a presence/absence dataset that we will use for modeling northern long-eared bat occupancy across the state.

Overall Project Outcomes and Results:

The Northern long-eared bat's (NLEB) listing as threatened under the federal Endangered Species Act prompted the DNR to undertake this project. The federal listing was in response to the impact of White Nose Syndrome (WNS) on bats throughout North America. WNS was detected in Minnesota in 2016, and NLEB hibernating in the Soudan mine subsequently declined drastically. The project first (Activity 1) compiled historic data to identify past distribution of NLEB. We next (Activity 2) deployed acoustic detectors throughout the forested region of

Minnesota and found NLEB at over half of the detector sites. Bats most common in southern Minnesota were NLEB, big brown bat, red bat, little brown bat, and silver-haired bat. In northern Minnesota, NLEB, little brown bat, and silver-haired bat were most common.

In Activity 3, we used radiotelemetry to locate bat roost trees. We captured 1,202 bats, with little brown bat (37%), big brown bat (31%), and NLEB (17%) most common. Pregnant females were captured into the third week of July, with lactating females more common after the last week of June. Juveniles were captured from the 3rd week of June to the end of July. We tracked 83 female NLEB to 238 roost trees. Surprisingly, almost 80% of the time a roost tree was used for only 1 night before switching to a different roost tree, which meant females carried young to a different roost tree often. Maternity roost home range size for female NLEB was about 18 acres.

In Activity 4, we found that NLEB females roosted in 27 different tree species, with 90% of roosts in deciduous tree species and 10% in conifer species. Most roost trees were in upland forests. Aspen trees were used most in northern Minnesota, maple and aspen trees in central Minnesota, and oak in southern Minnesota. Female NLEB preferred roost trees surrounded by mature forest. Roost tree habitat in northern Minnesota is broadly distributed. In southern Minnesota, female NLEB selected a wider range of roost trees than in the north, probably reflecting the greater presence of agriculture and development. We mapped areas of Minnesota that should be suitable habitat for female NLEB while raising young, based on distribution of NLEB in Minnesota and forest characteristics.

Results of this project benefit Minnesota because we have identified roost tree habitat for NLEB that is critical for successful reproduction. We have identified when female NLEB are pregnant and lactating, and shown that young must be carried from one roost to another. The data collected in this project will enable development of management strategies to help recover the NLEB population, and can also be used for management of other bat species.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Analyze and Summarize Existing Bat Survey Data in Minnesota

Description: The goal of this activity is to analyze all existing Minnesota bat acoustic survey data available. This will allow us to establish bat presence. Existing bat survey data from available sources (Minnesota Department of Natural Resources [DNR], federal agencies, university researchers, private sector consultants, wind industry, etc.) will be collected, analyzed for northern long-eared bat calls, and summarized. We have already identified 17 different studies, some spanning multiple years, within Minnesota, in addition to acoustic data collected on the Minnesota Biological Survey. We will then identify gaps where additional acoustic surveys should be done, and make an initial estimate of distribution of northern long-eared bat (NLEB) in Minnesota.

Range maps of NLEB in the IUCN map for the species (IUCN 2008) include all of Minnesota, but unforested regions in the west and south that were formerly prairie will likely have fewer NLEB. Past acoustic work in southwest Minnesota did not detect NLEB. Therefore, of the study area regions, the northern half of Minnesota will likely have the highest numbers of NLEB.

The existing data were collected under several different protocols which may not meet the U.S. Fish and Wildlife Service (USFWS) data collection guidelines (U.S. Fish and Wildlife Service 2014b), but we will use them as a baseline for NLEB presence in the state. The USFWS guidelines recommend analyzing acoustic data by site and night using two different bat ID programs. We will use a high-frequency filter to determine whether any bat calls were recorded at a site. Then the software programs will be used to identify calls to species, and the results compared between programs. Sites with probable NLEB calls will be confirmed through visual qualitative analysis.

Budget Narrative: Of the $44,247, $10,869 will be used by DNR and $33,378 will be used by the University of Minnesota (UM) to collect, organize, and analyze acoustic data from all existing acoustic surveys for bats in Minnesota. The budget items for Activity 1 are wages and benefits for both DNR and UM, $1,369 for DNR direct support services and $1,000 for staff training in the use of acoustic analysis software for DNR, and an estimated $1,200 for acoustic software for UM.

Summary Budget Information for Activity 1:		
	ENRTF Budget:	**$ 44,247**
	Amount Spent:	**$ 44,247**
	Balance:	**$ 0**

Outcome	**Completion Date**
1. Identify existing sources of bat survey data	December 2015
2. Develop map of existing survey locations	March 2016
3. Analyze recordings for northern long-eared bat calls	March 2016
4. Develop geospatial and database summaries of all northern long-eared bat data	March 2016

Activity Status as of January 1, 2016:

We have identified potential sources of existing bat acoustic data including the Minnesota Department of Natural Resources, Superior National Forest, Chippewa National Forest, Enbridge Inc., and the University of Minnesota Duluth (Table 1). So far, we have compiled >22,000 call files from 104 sites across Minnesota. We have purchased Kaleidoscope Pro call analysis software and have begun analyzing these calls. We have also arranged for a bat acoustic analysis workshop to be held in March 2016, which personnel working on this project will attend.

Table 1. Summary of sources of existing bat data and status of efforts to compile and analyze data.

Data Source	Status
University of Minnesota – Duluth	Data compiled and analysis started
Superior National Forest	Data compiled
Chippewa National Forest	Data compiled
Minnesota Department of Natural Resources	Data compiled
Enbridge, Inc.	Data compiled

Activity Status as of July 1, 2016:

Many project personnel attended a bat acoustic data management and analysis workshop, held at NRRI in March. We purchased Sonobat 3 software, after the workshop demonstrated its usefulness when combined with other programs such as Kaleidoscope for full-spectrum data. We have finished analyzing all UMD data using Kaleidoscope and have compiled all results so far. We are still waiting on acoustic data from the MN DNR and Enbridge, Inc.

Activity Status as of January 1, 2017:

We have created summaries of acoustic survey results from UMD, Superior National Forest, and Chippewa National Forest. This includes spreadsheets of all bat call identifications, and a geodatabase of northern long-eared bat presence across the state. We are still waiting on data managers from other entities (MN DNR and Enbridge, Inc.) to provide summaries of their existing acoustic data.

Activity Status as of July 1, 2017:

We have collected and summarized all available existing acoustic survey results across the state. We were not able to acquire all data for proprietary or access reasons. Once our capture and acoustic fieldwork is complete, we will combine the data from the existing and new surveys in occupancy models.

Activity Status as of January 1, 2018:
We will use the summarized data along with new capture and acoustic occurrence data to create occupancy models for northern long-eared bats statewide, which will provided evidence for distribution across the forested area of Minnesota. We are in the process of converting the existing acoustic data into a presence/absence dataset for this modeling.

Final Report Summary:

Northern long-eared bats (NLEB) hibernate in caves and mines in the winter, and were thought to be historically common across Minnesota's forests during the summer. The first published reference to NLEB in MN was in a list of Minnesota mammals compiled by University of Minnesota professor C.E. Johnson in 1916, with the range described as the "entire state". Subsequent published records of NLEB are sparse, and mostly from hibernacula. In 1982, Bemidji State University professor Evan B. Hazard compiled a map of Minnesota townships with records of NLEB presence for the book Mammals of Minnesota. Additional surveys of Minnesota's bats were conducted by Gerda Nordquist and Elmer Birney in the early 1980's, which led to distribution maps and identification of the largest known hibernating population of NLEB in Minnesota, at the Soudan Underground Mine in St. Louis County.

We compiled acoustic data and results from 2003 – 2014 from 5 sources that were available, including 208 passive surveys, 47 active surveys, and 13 driving transects located in 21 Minnesota counties. About 100,000 call files were analyzed (for comparison, under Activity 2 we recorded about 300,000 call files from 200 passive surveys). Other acoustic surveys have been conducted, but results were not publicly available (e.g., surveys done by consulting companies in preparation for wind turbine deployments). When available, we re-analyzed the original acoustic data using the software program Kaleidoscope Pro. Most of the surveys were done in the northern half of the state, and most of the surveys had detections or possible detections of NLEB. Possible detections occur because the calls of little brown bat and NLEB are difficult to distinguish. The historical acoustic surveys document likely presence across the northern half of the state, and near the Twin Cities. In combination with historical records from museum specimens and other records, this would suggest that NLEB are present throughout the forested region of Minnesota.

ACTIVITY 2: Conduct Bat Surveys Throughout Minnesota's Forests
Description: Bats will be surveyed by recording and analyzing their "sonar" calls. Acoustic survey methods will be similar to those of the pilot study conducted by USFS Superior National Forest (SNF) and Minnesota Department of Natural Resources (DNR) personnel in 2013 and 2014, past work by the Minnesota Biological Survey (MBS), and surveys in northeast Minnesota. Surveys will be conducted throughout the forested portion of the state. Bats will be trapped as necessary to strengthen survey results. Survey data will be analyzed for northern long- eared bat calls, and combined with data summarized in Activity 1 to produce a map of the summer distribution of the northern long-eared bat in the forested region of Minnesota.

We will use full spectrum and/or zero crossing detectors to record bats in different forest types (see section II.E). Existing detectors we have are all Anabats. We will follow the survey guidelines developed by the U.S. Fish & Wildlife Service for summer surveys of the endangered Indiana bat (*M. sodalis*). These guidelines recommend a minimum of 4 detector-nights at 2 locations within each 0.5 km^2 site, with acoustic sampling beginning at sunset and ending at sunrise each night. Collecting acoustic data is also an efficient and cost-effective way to survey other bat species in an area, and could provide information on other species of bats in the future.

Budget Narrative: Of the $318,206, $8,244 will be used by DNR, $50,000 will be used by SNF, and $260,015 will be used by the University of Minnesota (UM). DNR and SNF budget items are for wages and benefits to design sampling protocol, deploy detectors, download and analyze acoustic data from new detector locations, supplies, and travel and field expenses, and $644 for DNR direct support services. UM budget items for Activity 2 are wages and benefits ($122,642 estimated), acoustic detectors ($76,500 = 38 at approx. $2,000 each), travel and field expenses (supplies, per diem and mileage expenses) ($60,873 estimated).

Summary Budget Information for Activity 2:	**ENRTF Budget:**	**$ 318,259**
	Amount Spent:	**$ 318,259**
	Balance:	**$ 0**

Outcome	**Completion Date**
1. Identify forested areas of the state needing additional bat surveys	March 2016
2. Design additional bat surveys	March 2016
3. Implement bat surveys	September 2016
4. Analyze survey data for northern long-eared bat calls	March 2017
5. Develop geospatial, database, and map summaries of survey data	March 2017

Activity Status as of January 1, 2016:

We purchased 25 full-spectrum acoustic detectors and deployed them at 98 locations in 2015. We recorded >12,000 calls at these sites. We have begun analyzing these data using Kaleidoscope Pro software. We have preliminary identification of MYSE calls at 17 of the 98 sites.

Activity Status as of July 1, 2016:

We have continued to deploy full-spectrum acoustic detectors across the forested region of MN this spring and summer. We have finished analyzing all 2015 full-spectrum data in Kaleidoscope, and have begun analyzing it in the Sonobat 3 program, as well. Acoustic detectors have been deployed in Aitkin, Carlton, Clearwater, Crow Wing, Hubbard, Itasca, Meeker, Mille Lacs, Pine, and St. Louis counties this year.

Activity Status as of January 1, 2017:

We have finished analyzing all 2015 acoustic data using both the Sonobat 3 and Kaleidoscope Pro software programs. We have confirmed northern long-eared bat calls at 10 sites, and possible northern long-eared bat calls at an additional 28 sites from 2015.

We conducted acoustic surveys at 155 locations across the state in 2016. We have so far analyzed data for 39 sites using the two software programs. This preliminary analysis confirms northern long-eared bat calls at 7 sites, and possible northern long-eared bat calls at an additional 23 sites.

Activity Status as of July 1, 2017:

We have finished analysis of all 2015 and 2016 acoustic data. In total, we successfully deployed acoustic detectors 229 times in 213 locations (some locations were resampled between years), recording over 185,000 acoustic files. Over 114,000 files have been identified as bat calls by at least one of the software programs used. We have confirmed northern long-eared bat calls at 52 sites, and possible northern long-eared bats calls at an additional 102 locations. We continue to deploy acoustic detectors in 2017, with 28 sites surveyed so far.

Activity Status as of January 1, 2018:

We deployed acoustic detectors at 70 sites in 2017, some of which were sampled in previous years. Analysis of new 2017 acoustic data is ongoing. So far, data from 38 sites have been analyzed in Kaleidoscope and Sonobat, with northern long-eared bats confirmed at 8 of those sites and an additional 21 sites with possible northern long-eared bat calls.

Final Report Summary:

We deployed acoustic detectors 288 times at 213 locations throughout the forested region of Minnesota. Of the 300,000 files that were recorded, about 125,000 files could be identified as bat calls. Calls were analyzed using both Sonobat software and Kaleidoscope Pro software. Kaleidoscope Pro software is more liberal in species identification, while Sonobat tends to identify calls as an unknown bat species if there is uncertainty in identification. From 2015 to 2017 there were on average about 118 bat calls per night at a detector site. Detector deployments were filtered to only include nights when the maximum temperature was > 12° F, no filtering was done for wind or precipitation events. Using detector deployment as the sampling unit to account for nightly variation in bat species presence, NLEB were detected at 75% of the sites using Sonobat software, and 43% of sites using the Kaleidoscope Pro software.

Other bat species were also identified. Big brown bats, little brown bats, silver-haired bats, and hoary bats were detected at over 70% of locations with Sonobat software, and over 85% of locations with the Kaleidoscope Pro software. On a per species basis, from 2% to over 30% of nights there were more than 10 calls per night. Overall, NLEB and the red bat were the least common bat species in the acoustic detector call files.

All species of bats were detected throughout the forested region of Minnesota, but the relative densities of species was different in the northern and southern parts of the state. In the southern half of the state the big brown bat was most frequently detected at about 35%, followed by the red bat at about 30%, the little brown bat at about 20%, and the silver-haired bat at about 10%. Less than 5% of calls were made by the hoary bat, NLEB, and the tri-colored bat.

In contrast, in the northern half of the state, the little brown bat made up over 50% of the calls detected, and the silver-haired bat made up about 20% of calls detected. The big brown bat, the red bat, and the hoary bat made up between 5% and 10% of calls, NLEB about 4%, and the tri-colored bat < 1% of calls.

One interesting aspect of the acoustic detector deployments was that at about 50% of the detector deployment sites at least 3 of the 7 bat species in Minnesota were detected. In some of the detector sites 6 of the 7 bat species were detected.

NLEB calls were visually confirmed at 28% of detector sites throughout the forested area of Minnesota, and identified by software as possibly present at an additional 67% of detector sites. There was no spatial trend either north/south or east/west in NLEB presence. Distribution of the other bat species were identified only by software, with the restrictive condition of Kaleidoscope Pro and Sonobat software having a consensus agreement on species identification. All species but the tri-colored bat had a similar distribution throughout the forested portion of Minnesota with consensus identification, the tri-colored bat was more limited to the southern part of Minnesota.

ACTIVITY 3: Identify Summer Northern Long-Eared Bat Habitat in Minnesota's Forests
Description: Trapping and radio-tagging bats is a difficult, personnel-intensive, and costly activity. This activity will deploy multiple bat trapping and tracking crews across the forested region of the state. University of Minnesota (UM), Minnesota Department of Natural Resources (DNR), and Superior National Forest (SNF) will collaborate on this activity. At least 15 capture sites with northern long-eared bats will be selected from a sample of forested regions of Minnesota in 2016 and 2017.

Mist-netting and tracking will take place during the maternity season for *Myotis* species of bats, which is generally June 1 – July 15. Mist-nets will be set up along potential travel corridors at each site, and netting will begin at sunset and continue for 3.5-5 hours. Up to 40 female bats will be captured at these sites, equipped with radio transmitters, and tracked to roost sites and maternity colonies. Captured bats will be identified to species, and photographs will be taken of diagnostic features if needed. Captured bats will be marked with numbered wing bands, and personnel will attach radio-transmitters to reproductive female northern long-eared bats of sufficient weight. Colony and roost size will be monitored during the critical reproductive period.

Budget Narrative: Of the $686,909, $64,833 will be used by DNR, $100,000 will be used by SNF, and $524,076 will be used by UM. DNR and SNF budget items are for wages and benefits to deploy mist nets, place radiotransmitters on bats, and monitor roost sites, for associated travel and field expenses, and $4,025 for DNR direct support services. UM budget items for Activity 3 are wages and benefits ($372,643 estimated), radiotransmitters, receivers, and mist net setups ($36,350), and travel and field expenses (supplies, per diem, and mileage ($113,083 estimated).

Summary Budget Information for Activity 3:	**ENRTF Budget:**	**$ 686,909**
	Amount Spent:	**$ 686,909**
	Balance:	**$ 0**

Outcome	Completion Date
1. Identify locations with evidence of northern long-eared bat summer populations	March 2016
2. Select study sites for trapping and tracking	March 2016
3. Capture bats, equip with radios, and track to roost sites	September 2017
4. Monitor maternity colonies and roost sites to estimate number of bats present	September 2017

Activity Status as of January 1, 2016:

With additional external funding, we were able to begin mist-netting in June 2015. We mist netted at 39 sites in 6 counties in June and July. We attached radio-transmitters to 24 adult female MYSE, and subsequently identified 73 unique roost sites. 97% (71) of roost sites were in trees, with 38% (27) of those in trembling aspen (*Populus tremuloides*) and 21% (15) in red maple (*Acer rubrum*). Roosts were also located in at least 13 other tree species. Two additional roost sites were located in buildings. We conducted 76 emergence counts on 51 MYSE roost trees, and observed bats exiting from the trees during 53 of those surveys. The number of bats exiting from a roost ranged from 1-79, with an average of 21.5 and median of 12.

Note that a typographical error in the original Work Plan has been corrected as follows: The Description section of this Activity (above) had incorrectly stated “At least 3 capture sites … will be selected …”. We had intended for this sentence to read “At least 15 capture sites … will be selected …” and have corrected this error.

Activity Status as of July 1, 2016:

We began mist-netting in early June 2016, and plan to continue through late July. So far, we have mist-netted at 36 sites, attaching radio-transmitters to 27 adult female MYSE. Mist-netting sites used by project partners were located in Carlton, Pine, Itasca, Aitkin, Beltrami, St. Louis, Morrison, Cass, Fillmore, Houston, and Winona counties. The radio-telemetry, emergence counts, and roost tree characterization work is ongoing, 52 new maternity roost trees have been identified.

Activity Status as of January 1, 2017:

We mist-netted bats at 62 sites in 2016 (including the 36 sites mentioned in the previous update), and captured 640 bats of all seven species native to Minnesota, including 93 northern long-eared bats. In July of 2016, crews on this project also captured the first confirmed evening bat (*Nycticeius humeralis*) in Minnesota.

We attached transmitters to 45 adult female northern long-eared bats in 2016 and were able to track 42 of those bats to their roosts. We identified 107 new roost trees in 2016, of at least 20 species. The most common tree species used were trembling aspen (21%), northern red/pin oak and red maple (15%). We also identified one roost in a building. We conducted 107 emergence surveys on 79 of the roost trees, and observed bats during 87 of those surveys. The number of bats emerging from one roost ranged from 0-71, and averaged 17.3.

In total this project has now captured and processed 846 bats of 8 species. We have successfully tracked 66 adult female northern long-eared bats and identified 178 roost trees in 16 counties.

Activity Status as of July 1, 2017:
We began mist-netting for the 2017 field season in the first full week of June. So far, we have captured 192 bats at 25 sites. Twenty-two northern long-eared bats have been captured, 18 of which were female. Transmitters were attached to 14 of those bats. Due to the low capture rate of northern long-eared bats compared to 2016, we decided to also attach transmitters to some of the other cave-hibernating bats. So far we have attached seven transmitters to little brown and big brown bats. We have identified 42 new northern long-eared bat roost trees and 4 roosts of other bat species.

Activity Status as of January 1, 2018:
Mist-netting efforts continued through late July 2017. In the 2017 field season, we captured 350 bats at 57 sites, and tracked 19 northern long-eared bats, 10 little brown bats, and eight big brown bats to their roosts. We identified 56 northern long-eared bat roost trees, 12 little brown bat roost trees, and 13 big brown bat roost trees. Northern long-eared bats roosted in at least 17 species of trees of varying diameter and decay stage. The most commonly used tree species for female northern long-eared bats were trembling aspen (15.1%) and white oak (13.2%).

Over the three years of this project, we have now captured 1204 bats of eight species. We have successfully tracked 85 adult female northern long-eared bats to 231 roost trees in 19 counties. Preliminary analysis of data has been summarized each year in an annual report (see Swingen *et al.* 2015, 2016, & 2017 in Dissemination section).

Final Report Summary:

Bats were present throughout the forested portion of Minnesota based on mist-netting, similar to the results in Activity 2. Overall, we conducted 156 nights of mist-netting in June and July of 2015 – 2017 in 26 counties, with multiple crews operating simultaneously across the state. The number of bats captured per site per night ranged from 0 – 38. At least one bat was captured on 141 (90%) of the 156 nights of netting.

We captured 1,202 bats, with little brown bat (37%) and big brown bat (31%) being the most common species captured. The third most common bat species captured was NLEB at 17%, followed by red bat at 8%, silver-haired bat at 5%, and hoary bat at 2%. Only 1 tri-colored bat was captured, and we also captured the first evening bat found in Minnesota (as mentioned above).

One trend in species composition that we observed was a decline in NLEB from 37% to 15% to 9% of captures in 2015, 2016, and 2017, respectively. As NLEB decreased, big brown bat seemed to increase most, although little brown bat increased in 2016. Unlike with acoustic detector data (Activity 2), mist-netting allows confirmed identifications. This decrease in NLEB could be related to the effects of White Nose Syndrome (WNS). We did detect an increasing amount of wing damage that could be attributed to WNS from 2015 to 2017.

The distribution of bat species based on mist-netting supported the conclusions from the acoustic detectors in Activity 2. All species except for tri-colored bat and evening bat were captured throughout the forested region of Minnesota. The one anomaly with respect to distributions was that there were many more captures of NLEB in mist-nets in the central portion of the state than were detected acoustically. We don’t know the reason for this.

We captured both pregnant NLEB and lactating NLEB. Females were pregnant until the last week of June, after which lactating females were caught more frequently. However, pregnant bats were captured into the third week of July. Juveniles were first captured the 3rd week of June, with a peak in the second and third weeks of July.

We attached transmitters with a 1 to 2 weeks lifespan to 117 bats, including 89 female NLEB. The original plan was to deploy transmitters only on reproductive female NLEB, but due to reductions in capture rates (especially in 2017), we attached some transmitters to non-reproductive adult female and to adult male NLEB, little brown bats, and big brown bats. Here we only present NLEB results.

We tracked 83 of the 89 female NLEB with radiotransmitters to 238 roost trees. The average tracking duration for female NLEB was 6.3 days (range 1 – 13), and they were tracked to between 1 – 7 unique roost trees. This showed that NLEB females switch roosts frequently. Surprisingly, almost 80% of the time the NLEB female only used a roost tree for 1 night, and then switched to a different roost tree. Perhaps even more unexpectedly, female NLEB spent only 1 night in a roost tree 88% of the time when they were lactating, compared to 72% of the time when they were pregnant. This would indicate that female NLEB are carrying their offspring to a different roost tree each night.

We were also able to estimate how far female NLEB would fly from roost trees to foraging locations each night. The average distance from the mist-net site to the roost tree was about 725 m (range 26 – 4,197 m). About 75% of the distances from mist-net site to roost tree were < 1 km. Distance between consecutive roosts was about 300 m (range 2 – 2,083 m). Maternity roost home range size for female NLEB with ≥ 4 roost trees was about 7 ha (18 acres) while the radiotransmitter was functioning.

We conducted 292 emergence surveys on 199 of the identified tree roosts. Bats were observed exiting the roost tree in 221 surveys at 160 tree roosts. Colony size when a female NLEB was in the roost tree (total count of bats emerging during one survey) ranged from 1 – 79 and averaged 15 bats. However, from 1 to 5 bats exited 40% of the nights, and fewer than 20 bats emerged on about 70% of nights. Characteristics of roost trees and the surrounding forest were identified in Activity 4.

ACTIVITY 4: Characterize Summer Northern Long-Eared Bat Habitat in Minnesota
Description: Roosts, colony trees, and stands identified in Activity 3 and randomly selected trees and stands nearby will be ecologically characterized. We will measure roost trees post-maternity season and prior to leaf drop, and will record variables including tree type, tree height, decay class, tree diameter, roost type (e.g. crevice, cavity, under loose bark), and roost height. Comparing used vs. available habitats will determine which ecological variables are important to roost site and habitat selection. Radio tracking data will also be used to estimate home range sizes. The resulting characterization of northern long-eared bat habitat and home range will be used by the Minnesota Department of Natural Resources (DNR) to develop forest management recommendations for protecting bat summer habitat in Minnesota.

To determine landscape attributes that influence species occupancy, habitat covariates will be identified and measured at each site. Potential habitat covariates include cover type, distance to roads and trails, density of roads and trails, distance to water, type of water feature, and Lidar derived estimates of stand height and canopy density. We will evaluate multiple buffer sizes to determine that scale which best predicts species occupancy. We may also add geographic parameters to account for differences in forest type throughout the forested region of Minnesota that may influence northern long-eared bat (NLEB) occupancy. We will also include variables associated with forest harvest (stand age, harvest type, snags, and harvest season) in candidate models.

We will develop a set of candidate occupancy models from the total set of habitat covariates. Combinations of covariates will be selected based on biological significance. We will rank candidate models and use model averaging to create a final model that will be used to map NLEB occupancy across the landscape, similar to what has been done previously for carnivores, warblers, and damselflies. The resulting model could also be used to predict species response to proposed management actions.

Budget Narrative: $200,585 will be used by the University of Minnesota (UM). UM budget items for Activity 4 are wages and benefits (estimated $141,982), and travel and field expenses (supplies, per diem and mileage expenses ($58,603 estimated).

Summary Budget Information for Activity 4:	**ENRTF Budget:**	**$ 200,585**
	Amount Spent:	**$ 200,585**
	Balance:	**$ 0**

Outcome	**Completion Date**
1. Characterize roosts, colony sites, and randomly selected sites nearby	March 2018
2. Summarize data on roosts, colony sites, and home range	June 2018
3. Develop generalized description of roost sites and maternity colonies	June 2018

Activity Status as of January 1, 2016:

We collected data at 70 roost trees and 80 random trees in 2015. Data collected included tree species, decay class, diameter at breast height (dbh), tree height, roost type, canopy cover, and stand basal area. Roosts were most often in trees with some signs of decline or decay, although some roosts were in healthy, live trees. The average roost tree diameter (34.6 cm) was greater than the average diameter of random trees (29.0 cm). Roosts were located in trees with diameters as small as 16 cm. Tree height, canopy cover, and stand basal area did not appear to differ at roost trees when compared to random trees.

Activity Status as of July 1, 2016:
Tree characterization work for 2016 is ongoing. We have identified at least 52 roost trees of 11 species. Most roosts identified so far are in live trees, although decay class varies. Roosts have been located in trees between 15.5 and 65.0 cm dbh. Crews are collecting data on random trees as well, and analysis of those data will take place in the fall.

Activity Status as of January 1, 2017:
We completed characterization on 107 roost trees and 216 random trees in 2016. The roost trees were of at least 20 species, and ranged from 10.7 – 107.0 cm DBH. The average DBH of roost trees (41.1 cm) was greater than that of random trees (36.6 cm). Roost tree height ranged from 9.3 ft to 98.3 ft and averaged 47.0 ft. Roost tree decay stage varied from healthy live trees to decayed, broken off snags, but the majority of roost trees (78%) were declining or dead. The average roost decay stage on our 1-9 scale (2.9) was greater than the average decay stage of random trees (1.9).

Activity Status as of July 1, 2017:
We are in the process of collecting tree characterization data for 2017 roosts. So far in 2017 we have collected data on 19 new roost trees of at least 8 species used by female northern long-eared bats. Similar to previous years, trees vary widely in size (33 cm – 72 cm) and decay, although many are in dying or dead trees. We will continue to collect data on roost trees and nearby random trees throughout the summer.

Activity Status as of January 1, 2018:
We collected data on 56 northern long-eared bat roost trees in 2017, 53 of which were used by adult female bats. The remaining three were used by an adult male northern long-eared bat. We also collected data on 12

little brown bat roost trees and 13 big brown bat roost trees. For each identified roost tree we also collected data on two randomly chosen nearby trees for selection comparisons. In 2017, female northern long-eared bat roost trees averaged 39.3 cm DBH, and had an average decay class of 2.7. This was greater than the average for the randomly selected trees, which had an average DBH of 34.8 cm and an average decay class of 2.1. We are now beginning to compile all three years of data for analysis.

Final Report Summary:

The analysis of roost tree characteristics is based on 83 female NLEB that were tracked to 234 roost trees in Activity 3. NLEB females roosted in 27 different tree species. About 90% of roost trees were deciduous species, and 10% were conifer species. Most of the roost trees were in upland forests. In northern Minnesota, aspen trees (genus *Populus*) were most commonly used as roosts. In central Minnesota, maple (genus *Acer*) and aspen trees were most commonly used, and in southern Minnesota, oak (genus *Quercus*) were most commonly used.

The average roost tree was 39 cm (15”) DBH (Diameter at Breast Height), with a range of 11 to 107 cm (4” to 42”). Height of roosts averaged 15 m (49’) with a range of 2.5 m to 31 m (8’ to 101’). The 2.5 m roost was in a broken snag. Roost trees tended to be taller than random trees in the area, and also tended to be more decayed.

NLEB females roosted in cavities 38% of the time and in crevices 37% of the time, in loose bark about 14% of the time, and in a broken branch or trunk 11% of the time. Cavities were formed by branches falling out or by bird excavations, and crevices were long cracks in the tree. Roost exits were 0.2 to 20 m above ground level (< 1’ to 65’), with 75% of roosts > 5 m (16’) above ground level. About 85% of roost trees had canopy coverage > 80%. Basal area at the roost tree averaged 99.8 sq. ft./acre, with a maximum of 350 sq. ft./acre.

We compared forest characteristics in an 800 m circular buffer around the roost tree to 10 random locations that were within 5 km of the roost tree. This allowed us to identify characteristics that NLEB females might be selecting for with respect to roost trees. We chose to use the Tree Dominated variable (TreeDom) in the LandFire satellite-based classification system. TreeDom was correlated with many other forest cover related variables we could have used, it was more than 20% different between the roost tree and the random locations, and it was the most consistent variable across the forested region of Minnesota. Using the mean and a measure of variance of roost tree locations in each ECS section would not fully describe the range of values in TreeDom that female NLEB selected. Therefore, we calculated the percent of the 800 m buffer that was tree dominated (TreeDom) for each roost tree and for random locations.

Using this approach, we determined that female NLEB seemed to prefer areas in which 80% of more of the 800 m circular buffer was tree dominated. In northeastern Minnesota, where forest is relatively contiguous, there was less difference in TreeDom between roost trees and random locations. In contrast, in southern Minnesota with more agricultural land and human development, there were large differences in TreeDom between roost trees and random locations.

Because TreeDom is available across Minnesota, it is possible to make predictions at the landscape level about habitat suitability for roost trees, extending beyond the specific locations where we mist-netted. When we did this, we found that female NLEB in northern Minnesota could be relatively broadly distributed across the landscape, which was supported by the acoustic detector results in Activity 2. In contrast, in southern Minnesota there are large sections of the landscape that are not forested, and do not meet the selection criteria used by female NLEB in northern Minnesota. In response to this, we detected flexibility by female NLEB in selection patterns for TreeDom. In southern Minnesota, female NLEB used areas with less forest cover than they selected in northern Minnesota when they were required to do so because forested areas were not contiguous. Overall, this approach makes it possible for us to map areas of Minnesota that should be suitable habitat for female

NLEB while raising young, based on distribution of NLEB in Minnesota (Activities 1 – 3) and forest characteristics (Activity 4).

V. DISSEMINATION:
Description: We will create a website to distribute information to the public, but this will be done after the project starts. The website will be modelled after other websites we maintain (e.g., www.nrri.umn.edu/moose).

In addition, we will also prepare and submit papers for publication in peer-reviewed journals.

We will also probably have periodic contact with print and broadcast media, given the nature of the project. These contacts will be documented.

Activity Status as of January 1, 2016:

1. Publications during this period:
2. Swingen, M., R. Baker, T. Catton, K. Kirschbaum, G. Nordquist, B. Dirks, and R. Moen. 2015. Preliminary summary of 2015 northern long-eared bat research in Minnesota. NRRI Technical Report No. NRRI/TR-2015/44.
3. Interviews were given by Ron Moen and Rich Baker to John Myers (Duluth News Tribune), and he observed mist-netting and telemetry in preparation for stories published in July and September 2015.
4. An interview was given to Dan Gunderson (MPR) by Rich Baker on 3 Sep 2015 for a future story.
5. A presentation on MYSE status and research in Minnesota was given by Morgan Swingen to the Wood Fiber Employees Joint Legislative Council Meeting in Cloquet, MN in October 2015.
6. A presentation was given by Rich Baker to the Minnesota Forest Industries Meeting on 18 Aug 2015.
7. News stories published during this period:
    a. Myers, John. *Clues, but not cures, for deadly white-nose syndrome.* Printed 18 July 2015, Grand Forks Herald, Grand Forks, ND.
    b. Myers, John. *Bat study hones-in on nesting trees.* Printed 18 July 2015, Grand Forks Herald, Grand Forks, ND. Printed as *Bat study focuses on nesting trees in northland as deadly disease spreads* 30 July 2015, Duluth News Tribune, Duluth, MN.
    c. Wurzer, Cathy. *Key to bats' health to be researched in Minnesota.* Radio interview with Rich Baker. Published 21 July 2015, Minnesota Public Radio.
    d. Myers, John. *Northern Minnesota study tracks nesting habits of threatened bats.* Printed 17 Sep 2015, Duluth News Tribune, Duluth, MN.

Activity Status as of July 1, 2016:

1. A poster presentation was given by Tim Catton (USDA-FS) at the U of M SFEC Annual Forestry and Wildlife Research Review in Cloquet, MN, on Jan 12, 2016
2. Morgan Swingen gave a presentation Minnesota bats to the UMD University for Seniors Course: "Rocks, Water, and Wood: The Natural Resources Research Institute" at the University of Minnesota Duluth on 2/24/2016.
3. Tim Catton (USDA-FS) presented a poster on the project at the Midwest Bat Working Group meeting in Columbus, OH, April 21-22.

4. Ron Moen gave a presentation on Summer Habitat Use by Bats in Managed Minnesota Forests to the National Council on Air and Stream Improvement (NCASI) Northern Regional Meeting in Wasau, WI on 5/3/2016. Forest industry representatives from Minnesota attended this meeting.
5. Ron Moen gave a presentation on the project at the Tuesday Group meeting in Ely, Minnesota on June 14, 2016. The Tuesday Group meets every Tuesday in Ely at the Grand Ely Lodge and Resort.
6. News stories published during this period:
    a. Marcotty, Josephine. *Devastating white-nose syndrome has reached Minnesota bats.* Printed 9 March 2016, Star Tribune, Minneapolis, MN.
    b. Gunderson, Dan. *As deadly bat disease takes hold in Minn., scientists focus on future.* Radio story with interviews with Ron Moen and Morgan Swingen. Published 23 June 2016, Minnesota Public Radio.

Project Status as of January 1, 2017:

1. Morgan Swingen gave a presentation on the project to the student interns at Cedar Creek Ecosystem Science Reserve in Bethel, MN on 7 July 2016.
2. Morgan Swingen gave a presentation titled "Update on northern long-eared bat research in Minnesota" as part of the University of Minnesota Sustainable Forests Education Cooperative Forestry Webinar Series, in Cloquet, MN on 15 November 2016.
3. Morgan Swingen presented preliminary results from the project to the USDA – Forest Service Threatened & Endangered Species Interagency Coordination Meeting in Duluth, MN on 14 Dec 2016.
4. Morgan Swingen gave a presentation summarizing the project at the quarterly meeting of the MN DNR Forestry Division Management Team in Duluth, MN on 15 Dec 2016.
5. News stories published during this period:
    a. Forum News Service. *Newly found bat is first new mammal species in Minnesota in 25 years.* Published 1 Aug 2016, Duluth News Tribune, Duluth, MN.
    b. Covington, Hannah. *New bat species wings its way into Minnesota.* Printed 2 Aug 2016, Star Tribune, Minneapolis, MN.
    c. Timmons, Bob. *Minnesota bats are caught in a fast-moving, deadly epidemic.* Printed 8 Aug 2016, Star Tribune, Minneapolis, MN.
6. Technical Reports that have been distributed to Mist netting sites.

    Overall Report:

    a. Swingen, M., R. Baker, T. Catton, K. Kirschbaum, G. Nordquist, B. Dirks, and R. Moen. 2016. Summary of 2016 Northern Long-eared Bat Research in Minnesota. NRRI Technical Report No. NRRI/TR-2016/41. University of Minnesota Duluth.

    Site-Level Reports:

    b. Swingen, M., C. Spak, G. Nordquist, and R. Baker. 2016. Summary of bat research in Beaver Creek Valley State Park, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42A.
    c. Swingen, M., R. Moen, and R. Baker. 2016. Summary of bat research in Cedar Creek Ecosystem Science Reserve, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42B.
    d. Swingen, M., T. Catton, K. Kirschbaum, R. Moen and R. Baker. 2016. Summary of bat research in Cloquet Forestry Center, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42C.
    e. Swingen, M., T. Catton, K. Kirschbaum, R. Moen and R. Baker. 2016. Summary of bat research in Chippewa National Forest, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42D.

f. Dirks, B., N. Dietz, and M. Swingen. 2016. Summary of bat research in Camp Ripley Training Center and Arden Hills Army Training Site, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42E.
g. Swingen, M., T. Catton, K. Kirschbaum, R. Moen and R. Baker. 2016. Summary of bat research in Hill River/Savanna and Solana State Forests, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42F.
h. Swingen, M., R. Moen, and R. Baker. 2016. Summary of bat research in Itasca State Park, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42G.
i. Swingen, M., C. Spak, G. Nordquist, and R. Baker. 2016. Summary of bat research in Forestville/Mystery Cave State Park, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42H.
j. Swingen, M., R. Moen, and R. Baker. 2016. Summary of bat research conducted at Roseau River WMA, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42I.
k. Swingen, M., R. Moen, and R. Baker. 2016. Summary of bat research in St. Croix State Park, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42J.
l. Swingen, M., T. Catton, K. Kirschbaum, R. Moen and R. Baker. 2016. Summary of bat research in Superior National Forest, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42K.
m. Swingen, M., C. Spak, G. Nordquist, and R. Baker. 2016. Summary of bat research in Whitewater WMA and State Park, MN 2016. NRRI Technical Report No. NRRI/TR-2016/42L.

Project Status as of July 1, 2017:

1. Morgan Swingen gave an oral presentation titled "Habitat use by northern long-eared bats (*Myotis septentrionalis*) in the forested region of Minnesota" at the 9th Annual Midwest Bat Working Group meeting, Madison, WI, April 6th, 2017.
2. Ron Moen gave a presentation and project update at a meeting with the MN DNR Forestry Division, St. Paul, MN, April 13th, 2017.
3. Richard Baker gave a presentation to the Minnesota Logger Education Program, Bemidji, MN April 18, 2017.

Project Status as of January 1, 2018:

1. Richard Baker gave a presentation summarizing the project results at the Society of American Foresters meeting, August 15th, 2017.
2. Tim Catton, Kari Kirschbaum, Morgan Swingen, and others staffed a bat research exhibit including sharing a poster about northern long-eared bat research in Minnesota National Forests at the Minnesota Bat Festival, Bloomington, MN, August 19th, 2017.
3. Richard Baker gave a presentation at a meeting of the North American Forest Owners and U.S. Fish and Wildlife Service staff, September 6th, 2017.
4. Richard Baker gave a presentation titled "Update on Minnesota Bat Research and the Lake States Bat HCP" to a meeting of Minnesota Forest Industries, Grand Rapids, MN, October 11th, 2017.
5. Morgan Swingen gave a presentation title "Bat Ecology & Research at NRRI" to the Minnesota Ecology class from Lake Superior College, Duluth, MN, December 1st, 2017.
6. Morgan Swingen gave a presentation on MN northern long-eared bat research to the St. Louis County Land Department Foresters and Forestry technicians, Virginia, MN, December 20th, 2017.
7. News stories published during this period:

    a. Breneman, June. *Seeing the forest for the bats.* Multimedia new story published 17 Aug, 2017 by the University of Minnesota Duluth, Duluth, MN. Story and video available at https://news.d.umn.edu/news-center/news/bat-research

8. Technical Reports Published during this period:

   Overall Report:

    a. Swingen, M., R. Moen, R. Baker, G. Nordquist, T. Catton, K. Kirschbaum, B. Dirks, and N. Dietz. 2017. Summary of 2017 Bat Research in Minnesota. NRRI Technical Report No. NRRI/TR-201740. University of Minnesota Duluth.

   Site-Level Reports:

    a. Dirks, B., N. Dietz, M. Swingen, R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research at Arden Hills Army Training Site, MN. NRRI Technical Report No. NRRI/TR-201741a. University of Minnesota Duluth.
    b. Swingen, M., G. Nordquist, R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Richard J. Dorer State Forest - Hay Creek Unit, MN. NRRI Technical Report No. NRRI/TR-201741b. University of Minnesota Duluth.
    c. Swingen, M., R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Cloquet Valley State Forest, MN. NRRI Technical Report No. NRRI/TR-201741c. University of Minnesota Duluth.
    d. Swingen, M., K. Kirschbaum, T. Catton, R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in the Chippewa National Forest and Surrounding Area. NRRI Technical Report No. NRRI/TR-201741d. University of Minnesota Duluth.
    e. Dirks, B., N. Dietz, M. Swingen, R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research at Camp Ripley Training Center, MN. NRRI Technical Report No. NRRI/TR-201741e. University of Minnesota Duluth.
    f. Swingen, M., G. Nordquist, R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Minnesota Valley National Wildlife Refuge - Louisville Swamp Unit, MN. NRRI Technical Report No. NRRI/TR-201741f. University of Minnesota Duluth.
    g. Swingen, M., R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Mille Lacs WMA & Rum River State Forest, MN. NRRI Technical Report No. NRRI/TR-201741g. University of Minnesota Duluth.
    h. Swingen, M., R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Nemadji State Forest, MN. NRRI Technical Report No. NRRI/TR-201741h. University of Minnesota Duluth.
    i. Swingen, M., R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Sherburne National Wildlife Refuge, MN. NRRI Technical Report No. NRRI/TR-201741i. University of Minnesota Duluth.
    j. Swingen, M., R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in Three Rivers Park District, MN. NRRI Technical Report No. NRRI/TR-201741j. University of Minnesota Duluth.
    k. Swingen, M., T. Catton, K. Kirschbaum, R. Moen, and R. Baker. 2017. Summary of 2017 Bat Research in the Superior National Forest, MN and Surrounding Area. NRRI Technical Report No. NRRI/TR-201741k. University of Minnesota Duluth.

Final Report Summary:

1. Morgan Swingen gave a presentation at the Annual Meeting of the Minnesota Chapter of The Wildlife Society in St. Cloud, Minnesota, on February 13, 2018. Co-authors included R. Moen, R. Baker, T. Catton, K. Kirshbaum, G. Nordquist, B. Dirks, and N. Dietz.
2. Morgan Swingen gave a presentation at the Joint North American Bat Working Group Meeting, in Roanoke, Virginia, United States on March 28, 2018. Co-authors included R. Moen, R. Baker, T. Catton, K. Kirshbaum, G. Nordquist, B. Dirks, and N. Dietz.
3. Technical reports summarizing the entire project. These reports are being finished in Fall 2018.
    a. **Activity 1**: Moen, R. and Swingen, M. 2018. Historical northern long-eared bat occurrence in Minnesota based on acoustic surveys. NRRI Technical Report No. NRRI/TR-2018/39. University of Minnesota Duluth.
    b. **Activity 2**: Swingen, M., M. Walker, R. Baker, and R. Moen. 2018. Bat Acoustic Surveys in Minnesota 2015 - 2017. NRRI Technical Report No. NRRI/TR-2018/39. University of Minnesota Duluth.
    c. **Activity 3**: Swingen, M., R. Moen, M. Walker, R. Baker, G. Nordquist, T. Catton, K. Kirschbaum, B. Dirks, and N. Dietz. 2018. Bat Radiotelemetry in Forested Areas of Minnesota 2015-2017. NRRI Technical Report No. NRRI/TR-2018/42. University of Minnesota Duluth.
    d. **Activity 4**: Moen, R., M. Swingen, M. Walker, R. Baker, G. Nordquist, T. Catton, K. Kirschbaum, B. Dirks, and N. Dietz. 2018. Analysis of Northern Long-Eared Bat Roost Tree Characteristics in Minnesota 2015-2017. NRRI Technical Report No. NRRI/TR-2018/41. University of Minnesota Duluth.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	**$ Amount**	**Overview Explanation**
DNR Total = $83,946		
Personnel:	$37,500	DNR Personnel: Project Technician: 30% FTE/yr over 2 yrs @ $50,000/yr (salary/fringe) (.3 x 2 x $50,000 = $30,000) Data Manager: 5% FTE/yr over 3 yrs @ $50,000/yr (salary/fringe) (.05 x 3 x $50,000 = $7,500)
Travel:	$25,408	Field travel: mileage from DNR headquarters to various forest field sites and return, lodging and meals during fieldwork
Equipment & Supplies:	$14,000	Acoustic analysis software ($2,500); mist nets ($6,000); field supplies (bug repellant, gloves, batteries, adhesive, flagging, decon, etc. ($5,500)
Direct Support Services	$6,083	Direct Support Services. DNR's direct and necessary costs pay for activities that are directly related to and necessary for accomplishing appropriated programs/projects. In addition to itemized costs captured in our

		proposal budget, direct and necessary costs cover HR Support ($995), Safety Support ($246), Financial Support ($1,019), Communication Support ($856), IT Support ($1,705), Planning Support ($528), Procurement Support ($176), and division and regional program management ($0) that are necessary to accomplishing funded programs/projects.
Other	$1,000	Staff training in use of acoustic analysis software
Professional/Technical/Service Contracts:		
1. University of Minnesota – contract Total=$1,016,054		
Personnel	$ 669,445	UM Personnel: 1 project coordinator (salary/benefits) at 1 FTE each year for 3 years; 1 field manager (salary/benefits) at 0.5 FTE for 1 year; 2 field managers (salary/benefits) each at 0.5 FTE each year for 2 years; project technician (salary/benefits) at 0.5 FTE for 1 year; 4 project technicians (salary/benefits) each at 0.5 FTE each year for 2 years; 1 project technician (salary/benefits) at 1 FTE for 1 year; 1 ecologist (salary/benefits) at 1 FTE for 1 year
Equipment/Tools/Supplies:	$ 114,050	Acoustic detectors (38), transmitters (135), receivers and antennae (8), software (1), and nets, poles, and pulleys (7); field supplies, e.g., bug spray, gloves, batteries
Travel Expenses in MN:	$ 232,559	In-state travel mileage for all project activities and field Expenses (lodging & meals): 19 staff field seasons x 24 wk/season @ $450/wk
2. Superior National Forest – contract Total=$150,000		
Personnel	$ 150,000	SNF (contract) Personnel: 2 project technicians (salary/benefits) at 0.5 FTE for 1 year; 2 project technicians (salary/benefits) at 0.5 FTE each year for 2 years
TOTAL ENRTF BUDGET:	**$ 1,250,000**	

Explanation of Use of Classified Staff: Project funding will provide partial support for full-time classified staff who are uniquely qualified to complete tasks required by this project. During the time that a portion of these employees time is redirected to this project, their responsibilities will be back-filled by temporary staff who do not have the skills to complete these tasks.

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

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.50 FTEs

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 8.67 FTEs

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Secured			
Superior National Forest and Chippewa National Forest	$ 145,000	$ 145,000	Supplement acoustic surveys, netting, and roost/colony monitoring on U.S. Forest Service lands
Blandin Foundation	$ 7,500	$ 7,500	Acoustic detection, mist-netting and radiotelemetry.
NCASI	$ 25,000	$ 25,000	Acoustic detection, mist-netting and radiotelemetry on NLEB and other species.
Pending			
Camp Ripley Training Center	$ 65,200	$ 0	Training Center staff have applied for Department of Defense Legacy Resource Management Program grant to supplement acoustic surveys, netting, and roost/colony monitoring in Camp Ripley
Minnesota's Lake Superior Coastal Program Grants	$ 15,000	$ 0	UMD has submitted a proposal for additional bat monitoring in the Lake Superior watershed
Minnesota's Lake Superior Coastal Program Grants	$ 50,000	$ 0	UMD will be submitting a proposal for additional bat monitoring in the Lake Superior watershed
Sea Grant	$ 200,000	$ 0	UMD will be submitting a proposal to support expansion of the project in the vicinity of the St. Louis River Estuary
State			
Nongame Wildlife Program Staff Time (in-kind)	$ 50,000	$ 50,000	Various
TOTAL OTHER FUNDS:	**$ 607,700**	**$ 227,500**	

VII. PROJECT STRATEGY:

A. Project Partners:

The overall project will be managed by the DNR's Division of Ecological and Water Resources (Richard Baker, Endangered Species Coordinator, and Gerda Nordquist, Minnesota Biological Survey Mammalogist) in close cooperation with the Division of Forestry (Amber Ellering, Planner). Project Coordination and Implementation will be handled by the University of Minnesota, Duluth/Natural Resources Research Institute (Dr. Ron Moen, Mammalogist) in cooperation with the U.S. Forest Service.

B. Project Impact and Long-term Strategy:

This project will provide scientific data on the timing and use of forest stands and individual trees by northern long-eared bats during summer. These data will allow the DNR to develop forest management recommendations for protecting bat summer habitat in Minnesota more effectively than would a broad tree removal prohibition. When, as expected, white-nose syndrome infects the state's bat populations, the results of this project will be valuable in mitigating the disease's impacts on all cave bat species. The project's results will also be useful to on-going efforts to mitigate the impacts of wind power development on the state's bat populations. Additional funding will not be required to meet these goals.

C. Funding History:

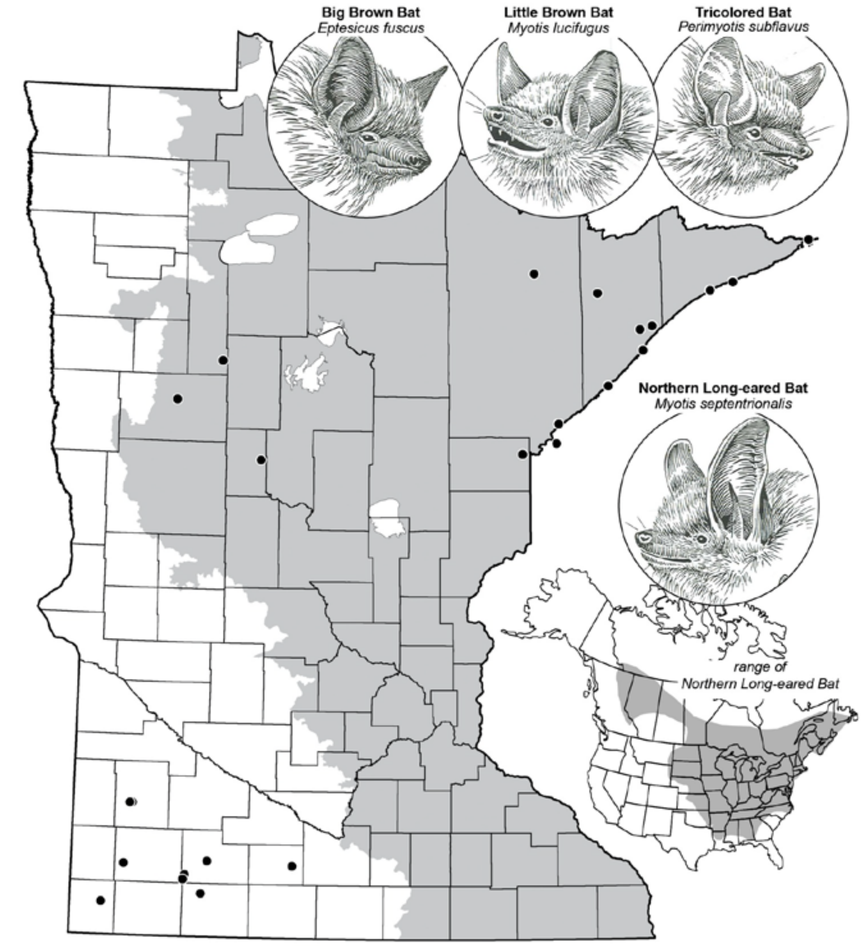
Funding Source and Use of Funds	Funding Timeframe	$ Amount
A pilot project is being jointly implemented by DNR, Superior National Forest, and Camp Ripley Training Center in 2014 to test methodology that will be used in the proposed ENRTF project. Support for the pilot project is being shared by the DNR (Division of Ecological and Water Resources, Division of Parks and Trails, Division of Forestry), Superior National Forest, U.S. Fish and Wildlife Service, and Camp Ripley Training Center.	2014	$ 117,570

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):



Map of Minnesota showing:
- forested portion of the state that will be focus of project (shaded)
- locations of acoustic bat surveys as of 2008 (dots)
- range of Northern Long-eared Bat in North America (inset)
- Minnesota's cave-hibernating bat species Illustrations by Don Luce, courtesy of the James Ford Bell Museum of Natural History

X. RESEARCH ADDENDUM:
See attached Research Addendum.

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than January 1, 2016; July 1, 2016; January 1, 2017; July 1, 2017; and January 1, 2018. A final report and associated products will be submitted between June 30 and August 15, 2018.

Environment and Natural Resources Trust Fund
M.L. 2015 Final Project Budget
Project Title: Endangered Bats, White-Nose Syndrome, and Forest Habitat
Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03i
Project Manager: Richard Baker
Organization: MN DNR
M.L. 2015 ENRTF Appropriation: $ 1,250,000
Project Length and Completion Date: 3 years, June 30, 2018
Date of Report: 19 November 2018

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	Activity 4 Budget	Amount Spent	Activity 4 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	*Analyze and Summarize Existing Bat Survey Data in Minnesota*			*Conduct Bat Surveys Throughout Minnesota's Forests*			*Identify Summer Northern Long-Eared Bat Habitat in Minnesota's Forests*			*Characterize Summer Northern Long-Eared Bat Habitat in Minnesota*				
Personnel (Wages and Benefits)	$8,500	$8,500	$0	$4,000	$4,000	$0	$25,000	$25,000	$0	$0	$0	$0	$37,500	$0
Project Technician: 30% FTE/yr over 2 yrs @ $50,000/yr (salary/fringe) (.3 x 2 x $50,000 = $30,000)														
Data Manager: 5% FTE/yr over 3 yrs @ $50,000/yr (salary/fringe). (.05 x 3 x $50,000 = $7,500)														
Equipment/Tools/Supplies	$0	$0	$0	$100	$100	$0	$13,900	$13,900	$0	$0	$0	$0	$14,000	$0
Acoustic analysis software ($2,500); mist nets ($6,000); field supplies (bug repellant, gloves, batteries, adhesive, flagging, decon, etc. ($5,500)														
Travel expenses in Minnesota	$0	$0	$0	$3,500	$3,500	$0	$21,908	$21,908	$0	$0	$0	$0	$25,408	$0
Field travel: mileage from DNR headquarters to various forest field sites and return, lodging and meals during fieldwork														
Other	$2,369	$2,369	$0	$644	$644	$0	$4,025	$4,025	$0	$0	$0	$0	$7,038	$0
Direct Support Services. DNR's direct and necessary costs pay for activities that are directly related to and necessary for accomplishing appropriated programs/projects. In addition to itemized costs captured in our proposal budget, direct and necessary costs cover HR Support ($995), Safety Support ($246), Financial Support ($1,019), Communication Support ($856), IT Support ($1,705), Planning Support ($528), Procurement Support ($176), and division and regional program management ($0) that are necessary to accomplishing funded programs/projects.														
Staff training in use of acoustic analysis software ($1,000)														
Professional/Technical/Service Contracts with DNR														
1. University of Minnesota Contract ($1,016,054)														
Personnel (Wages and Benefits)	$32,178	$32,178	$0	$122,642	$122,642	$0	$372,643	$372,643	$0	$141,982	$141,982	$0	$669,445	$0
Project Coordinator (UM): $69,700 (salary/fringe); 100% FTE each year for 3 yrs (est. $209,066)														
5 Field Manager years (UM): $56,610 (salary/benefits) each at 50% FTE (est. $141,510)														
11 Project Technician years (UM): $47,685 (salary/benefits) each at 50% FTE (est. $262,265)														
Ecologist (UM): $56,604 (salary/benefits) at 100% FTE for 1 year (est. $56,604)														
Equipment/Tools/Supplies	$1,200	$1,200	$0	$76,500	$76,500	$0	$36,350	$36,350	$0	$0	$0	$0	$114,050	$0
Acoustic detectors (38 @ est. $2,000), Transmitters (135 @ est. $150), Receivers and antennae (8 @ est. $1,000), Acoustic software (1 @ est. $1,200), Mist nets, poles, pulleys (7 @ est. $800), Field supplies (e.g., bug spray, gloves, batteries) est. $3,000)).														
Travel expenses in Minnesota	$0	$0	$0	$60,873	$60,873	$0	$113,083	$113,083	$0	$58,603	$58,603	$0	$232,559	$0
Field travel estimated lodging and meals for ~19 staff x 24 weeks/field season (~$450/week per staff), In-state travel mileage ($0.56/mi) for all project activities.														
2. Superior National Forest Contract ($150,000)														
Personnel (Wages and Benefits)	$0	$0	$0	$50,000	$50,000	$0	$100,000	$100,000	$0	$0	$0	$0	$150,000	$0
6 Project Technician years (SNF): $50,000 (salary/benefits) at 50% FTE ($150,000)														
COLUMN TOTAL	**$44,247**	**$44,247**	**$0**	**$318,259**	**$318,259**	**$0**	**$686,909**	**$686,909**	**$0**	**$200,585**	**$200,585**	**$0**	**$1,250,000**	**$0**

Summary of 2016 Northern Long-eared Bat Research in Minnesota

Morgan Swingen[1], Richard Baker[2], Timothy Catton[3], Kari Kirschbaum[4], Gerda Nordquist[5], Brian Dirks[6], Ron Moen[1,7]

December 2016

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NRRI Technical Report No. NRRI/TR-2016-41 Release 1.0

Please contact authors before citing as manuscripts are in review and in preparation
If corrections are made to this Technical Report they will be posted at https://d-commons.d.umn.edu/

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Summary

Crews from the USDA – Forest Service, University of Minnesota - Natural Resources Research Institute, Minnesota Army National Guard (MNARNG), and Minnesota Department of Natural Resources captured 646 bats throughout the forested region of Minnesota from June 6 – July 21, 2016. Bats of 8 species were captured during mist-netting surveys, including the first evening bat (*Nycticeius humeralis*) confirmed in Minnesota. We captured 95 individuals of our target species, the northern long-eared bat, and attached transmitters to 45 adult females (39 reproductive, 6 non-reproductive or undetermined). These 45 bats were tracked to 111 unique roost trees of at least 20 species. Crews conducted emergence counts at roost trees and observed between 1-71 bats emerging. Roost trees varied in both DBH and height, as well as decay stage. The roosting patterns observed in 2016 were similar to those seen in 2015, where bats appear to be using a variety of available trees.

Introduction

Bats are an important part of Minnesota's ecosystems, likely providing many millions of dollars in pest control each year (Boyles et al. 2011). Seven species of bats are known residents of Minnesota: little brown bats (*Myotis lucifugus*, MYLU), northern long-eared bats (*Myotis septentrionalis*, MYSE), big brown bats (*Eptesicus fuscus*, EPFU), tricolored bats (*Perimyotis subflavus*, PESU), silver-haired bats (*Lasionycteris noctivagans*, LANO), eastern red bats (*Lasiurus borealis*, LABO), and hoary bats (*Lasiurus cinereus*, LACI). Four Minnesota bat species (MYSE, MYLU, EPFU, and PESU) hibernate in caves during the winter, and disperse widely across the state in spring, summer, and fall. Very little is known about the summer habitat use of these species.

The northern long-eared bat was listed as Threatened under the federal Endangered Species Act in April 2015, largely due to the impact of white-nose syndrome (U.S. Fish and Wildlife Service 2016). White-Nose Syndrome (WNS) is caused by the fungus *Pseudogymnoascus destructans* which leads to increased winter activity and extremely high mortality rates of cave-hibernating bats (Frick et al. 2010). WNS was discovered in New York state in 2006, and has been spreading through bat populations in the eastern U.S. states and Canadian provinces, with range expansions of WNS occurring every year (Turner et al. 2011). Winter hibernacula monitoring detected *P. destructans* in Minnesota in 2013, and recorded the first bat mortalities during January 2016 at Lake Vermilion - Soudan Underground Mine State Park (Minnesota Department of Natural Resources 2013, 2016a). Maintaining reproductive success will be critical to the viability of Minnesota's bat populations as WNS spreads in Minnesota. Obtaining knowledge about maternity roosts before a population decline occurs will be critical for future efforts to reduce negative impacts of forest management and provide high quality habitat to support recovery of bat populations. Implementing management strategies that minimize mortality will be of over-riding importance as WNS continues to affect Minnesota bats.

In 2015, the Minnesota legislature approved $1.25 million in Environment and Natural Resources Trust Fund (ENRTF) funding for the project *Endangered Bats, White-Nose Syndrome, and Forest Habitat* (M.L. 2015 Project 004-A), the goal of which is to collect data on the distribution and habitat use of the northern long-eared bat in Minnesota. This project is being conducted by the Minnesota Department of Natural Resources (MNDNR), the University of Minnesota Duluth – Natural Resources Research Institute (NRRI), the Minnesota Army National Guard (MNARNG), and the USDA-Forest Service (USFS). We are collecting data from across the state during 2015-2017. Preliminary data from 2015 were summarized in a report released in the fall of 2015 (Swingen et al. 2015). This report summarizes results from the 2016 field season of the ENRTF-funded project, with support from additional funding sources.

Methods

Bat Capture/Processing

Field crews set up fine mesh mist-nets (Avinet Inc, Dryden, NY, USA) along forested roads that could act as travel corridors for bats. Each night, 2-4 mist-nets were set up within 200 m of a central processing location. We opened mist-nets after sunset, and checked them every 15 minutes for 2-5 hours, depending on capture rates and weather conditions.

We identified each captured bat to species, and determined sex, age, and reproductive condition by physical examination. Each bat was also weighed and measured, and the wings were inspected for damage potentially caused by white-nose syndrome (Fig. 1, Fig. 2). Wing condition was scored from 0-3 according to the Reichard wing-damage index (Reichard and Kunz 2009). We then fitted each bat with an individually-numbered lipped aluminum wing band (Porzana Ltd., Icklesham, United Kingdom).

Figure 1. Photos showing the techniques for capturing and processing bats. Photo Credits: A – Superior National Forest; B, D – Brian Houck, NRRI; C – Peter Kienzler, NRRI.

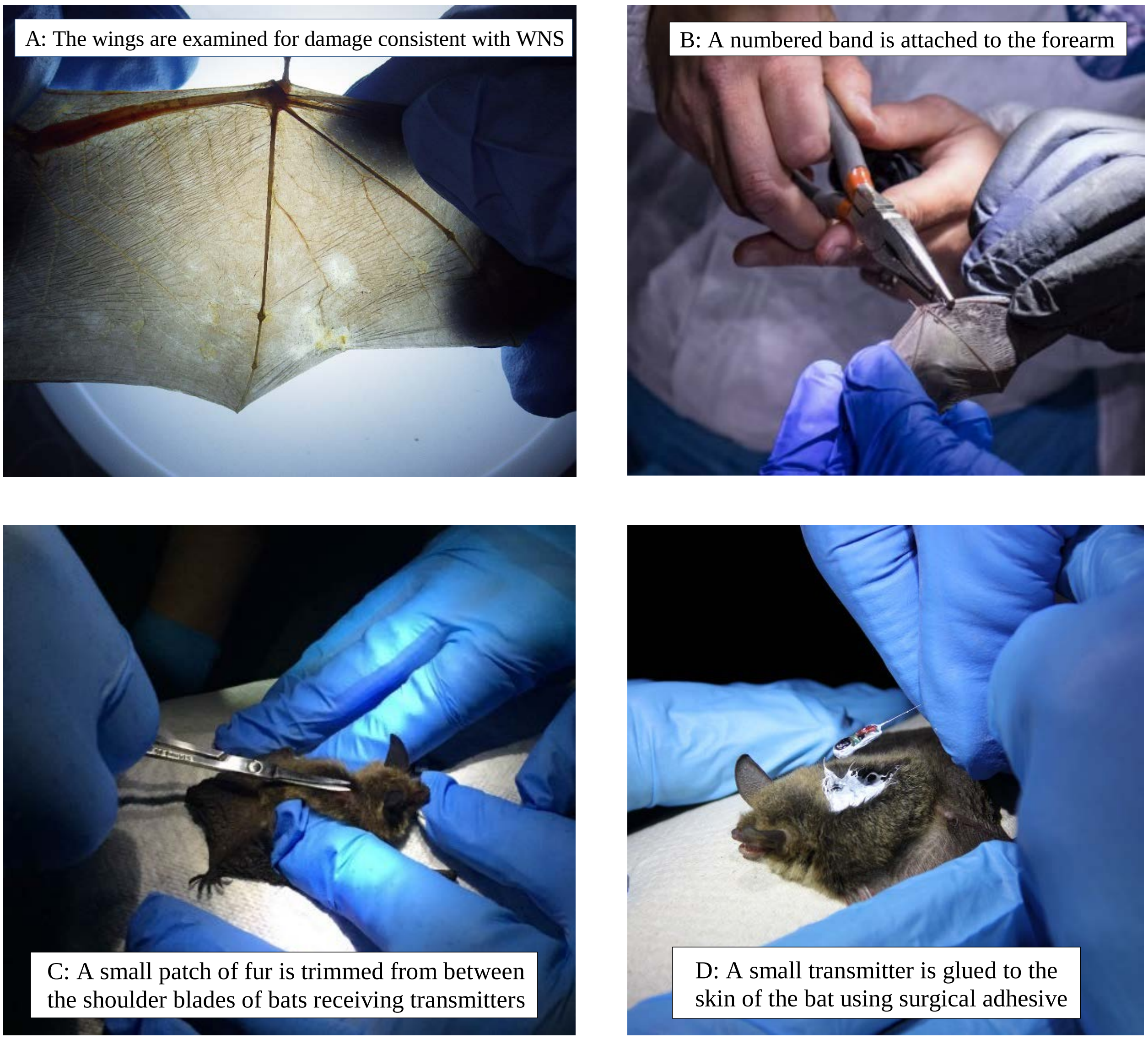
A: Mist-nets are raised on poles with a pulley system

B: A bat flies into the mist-net and is caught

C: Bats are handled with disposable nitrile gloves to prevent spread of WNS between bats

D: Bats are temporarily placed in plastic bags to measure the length of the forearm

Figure 2. Photos showing techniques for processing bats and attaching bands and transmitters. Photo Credits: A – Christi Spak, MN DNR; B – Ryan Pennesi, USFS; C – Sarah Baker, NRRI D – Morgan Swingen, NRRI.



Field crews attached radio-transmitters (A2414 Advanced Telemetry Systems Inc., Isanti, MN; or LB-2X, Holohil Systems Ltd., Carp, ON, Canada) to adult female MYSE. We trimmed a section of hair in the center of the back, and used surgical adhesive (Perma-Type, Permatype Company Inc., Plainville, CT, USA) to attach the transmitter to the skin (Fig. 2). We released all bats at the capture site after processing.

Tracking/Roost Tree Characterization

We tracked bats with radio-transmitters daily to their roosts using radio telemetry until the transmitter failed or fell off. Data recorded at each roost included roost type, tree species, and decay stage. At dusk, crews returned to the roost trees to conduct emergence surveys. During an emergence survey, personnel watched the roost tree from 30 minutes before sunset to 1 hour after sunset. During the survey we recorded the number of bats emerging during each 10-minute interval, the location of the exit point, and whether or not the transmitter left the tree.

Crews returned to each roost tree to conduct a more detailed tree characterization after bats left. This included measuring roost diameter at breast height (dbh), tree height, decay stage, canopy closure, slope, aspect, and recording details about the vegetation surrounding the roost tree. The same data were collected at two randomly chosen trees within 200 m from the roost tree. We used two-tailed unequal variances t-tests ($\alpha = 0.05$) to compare measurements of roost trees to random trees.

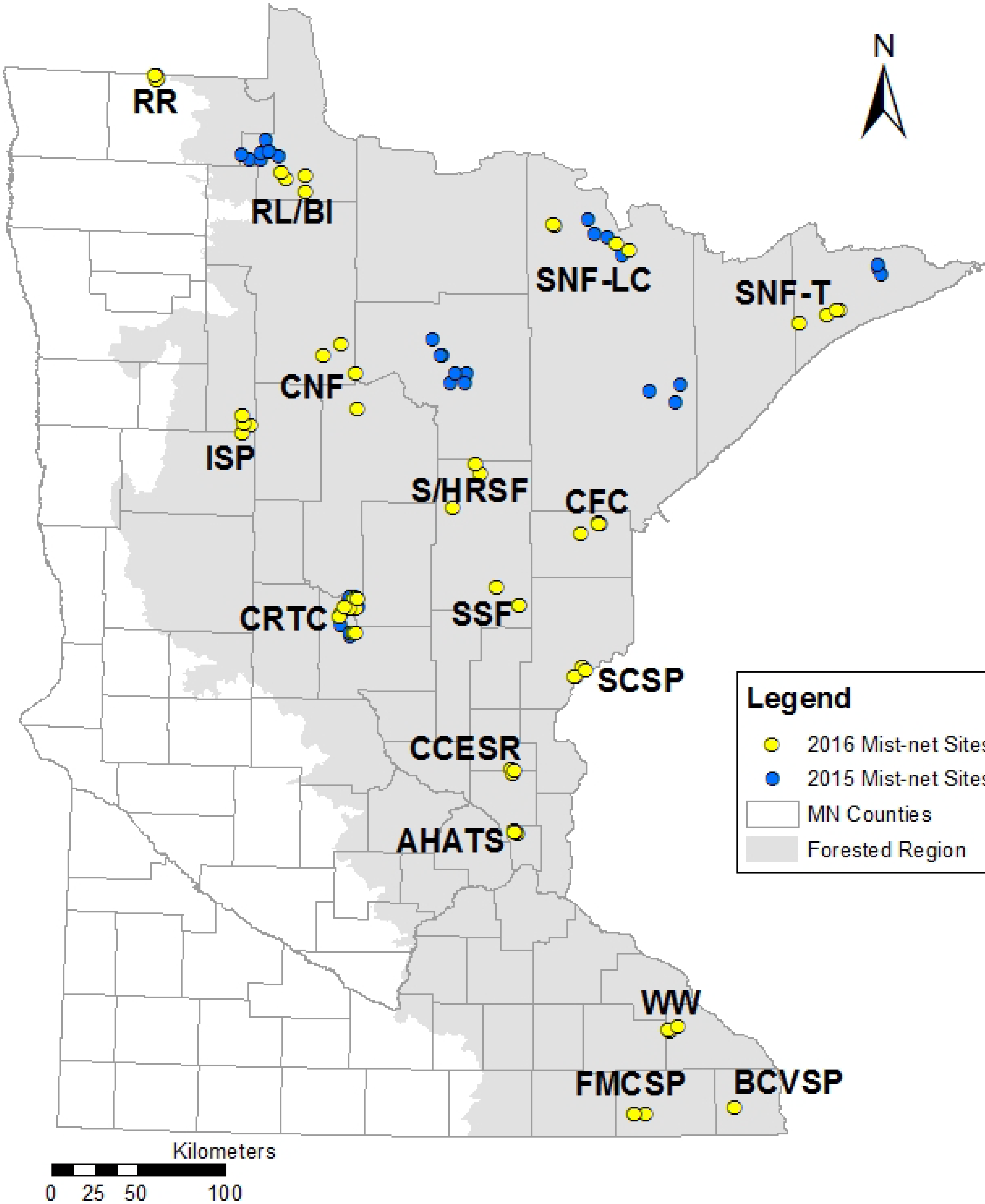
Study Area

We captured bats with mist-nets at 16 study areas throughout the forested region of the state of Minnesota (Table 1, Fig. 3).

Table 1. Names and abbreviations of study areas and dates during which bat mist-netting took place during the 2016 field season.

Study Area Name	**Abbreviation**	**MN County**	**Ownership**	**Net Dates**
Arden Hills Army Training Site	AHATS	Ramsey	Federal	7/6 - 7/9
Beaver Creek Valley State Park	BCVSP	Houston	State	6/18
Camp Ripley Training Center	CRTC	Morrison, Crow Wing	State	6/6 - 6/23
Cedar Creek Ecosystem Science Reserve	CCESR	Anoka, Isanti	University of MN	7/6 - 7/8
Cloquet Forestry Center	CFC	Carlton	University of MN	6/6 - 6/9
Chippewa National Forest – Blackduck and Walker Districts	CNF	Beltrami, Cass, Itasca	Federal	6/20 - 6/23
Forestville/Mystery Cave State Park	FMCSP	Fillmore	State	6/7 - 6/9
Itasca State Park	ISP	Becker, Clearwater, Hubbard	State	6/13 - 6/16
Red Lake WMA/Beltrami Island State Forest	RL/BI	Lake of the Woods, Roseau	State	7/12 - 7/15
Roseau River Wildlife Management Area	RR	Roseau	State	7/11 - 7/14
Savanna/Hill River State Forests	S/HRSF	Aitkin, St. Louis	State	6/13 - 6/16
Superior National Forest – LaCroix District	SNF-LC	Koochiching, St. Louis	Federal	6/27 - 6/30
Superior National Forest – Tofte District	SNF-T	Cook, Lake	Federal	7/18 - 7/21
Solana State Forest	SSF	Aitkin	State	7/11 - 7/14
St. Croix State Park	SCSP	Pine	State	6/26 - 6/29
Whitewater SP/Whitewater WMA	WW	Winona	State	6/15 - 6/17

Figure 3. Map of all 2015 and 2016 mist-netting locations. Mist-netting sites are generally clustered in groups of 2-4 in each location. 2016 study areas are labeled with abbrevations as listed in Table 1.



Results

Mist-Netting

We conducted 62 nights of mist-netting between June 6th and July 21st, 2016, with multiple crews operating simultaneously across the state. Mist-netting took place for 3 or 4 nights at each study area, with the exception of Beaver Creek Valley State Park which had only one night of mist-netting, and Camp Ripley Training Center which had 10 nights of mist-netting.

Species Captured

We captured and processed 646 bats over 900 net-hours (Fig. 4). We captured individuals of all seven native bat species, and also captured the first confirmed evening bat (*Nycticeius humeralis*) in Minnesota (Fig. 5, Table 2).

Figure 4. Map of bat mist-netting capture results in 2016 for all species. Capture results are displayed by site as listed in Table 1. The size of the symbol at each site represents the capture rate (bats/net-hour), and the label at each site indicates the total number of individuals captured.

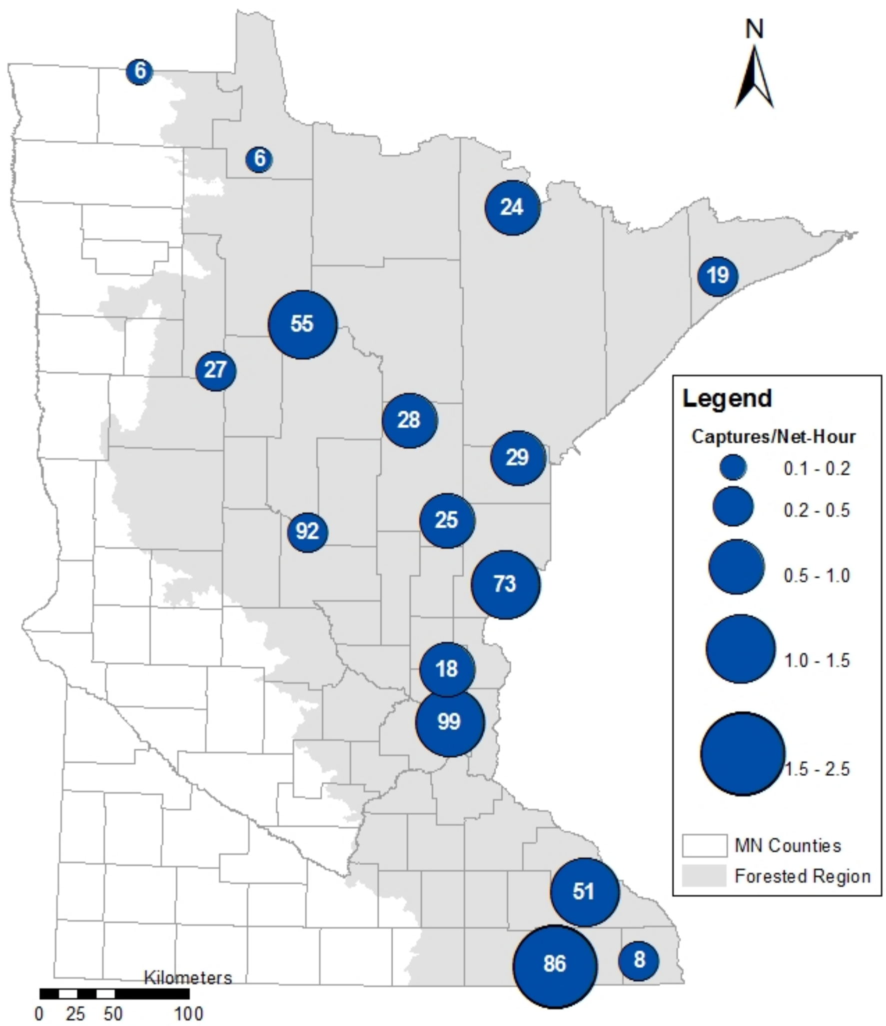


Figure 5. Maps of bat mist-netting capture results by species in 2016. Capture results are displayed by site as listed in Table 1. See Table 2 for total captures by species.

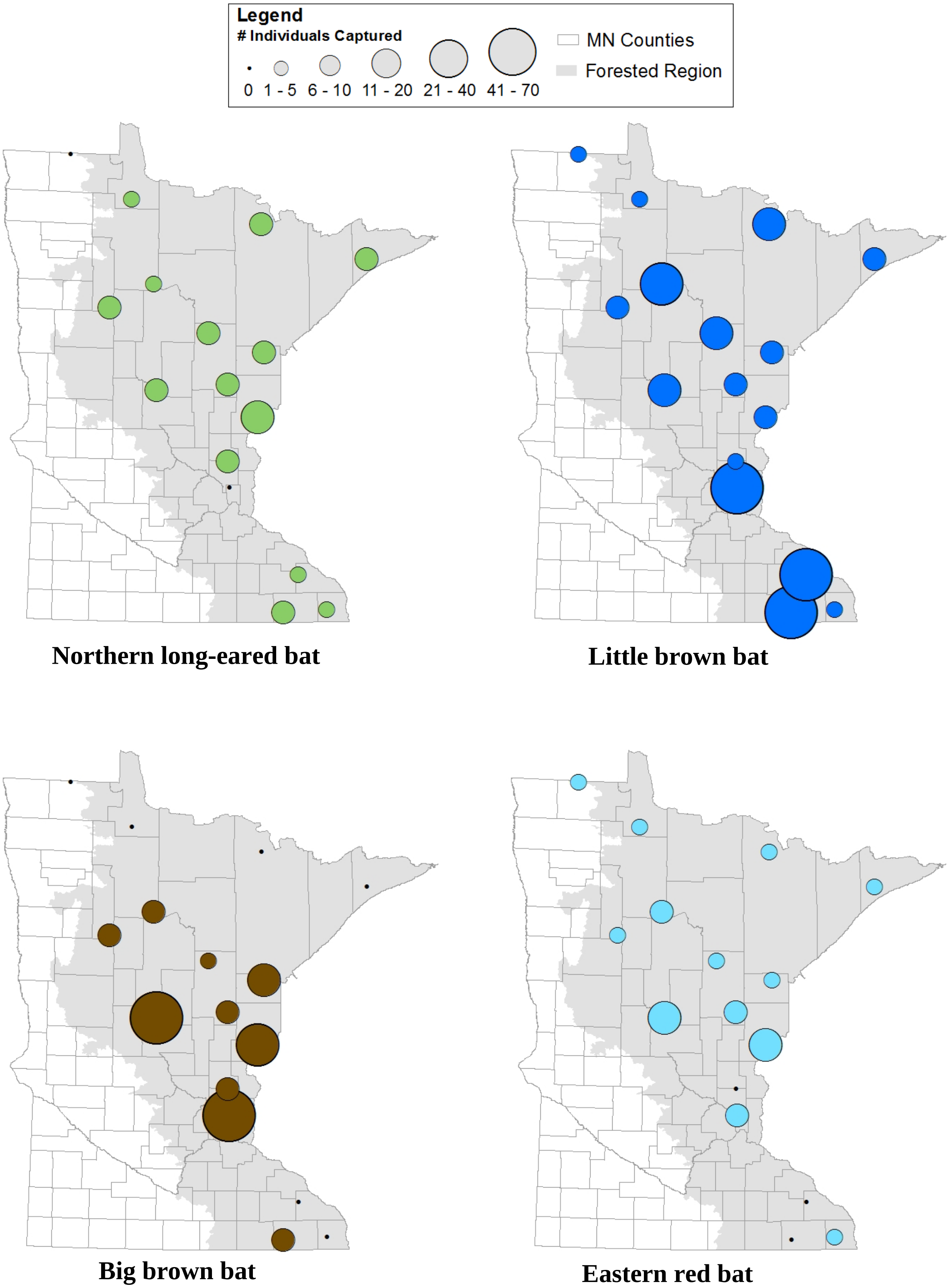


Figure 5 continued. Maps of bat mist-netting capture results by species in 2016. Capture results are displayed by site as listed in Table 1. See Figure 4 for capture totals at each site.

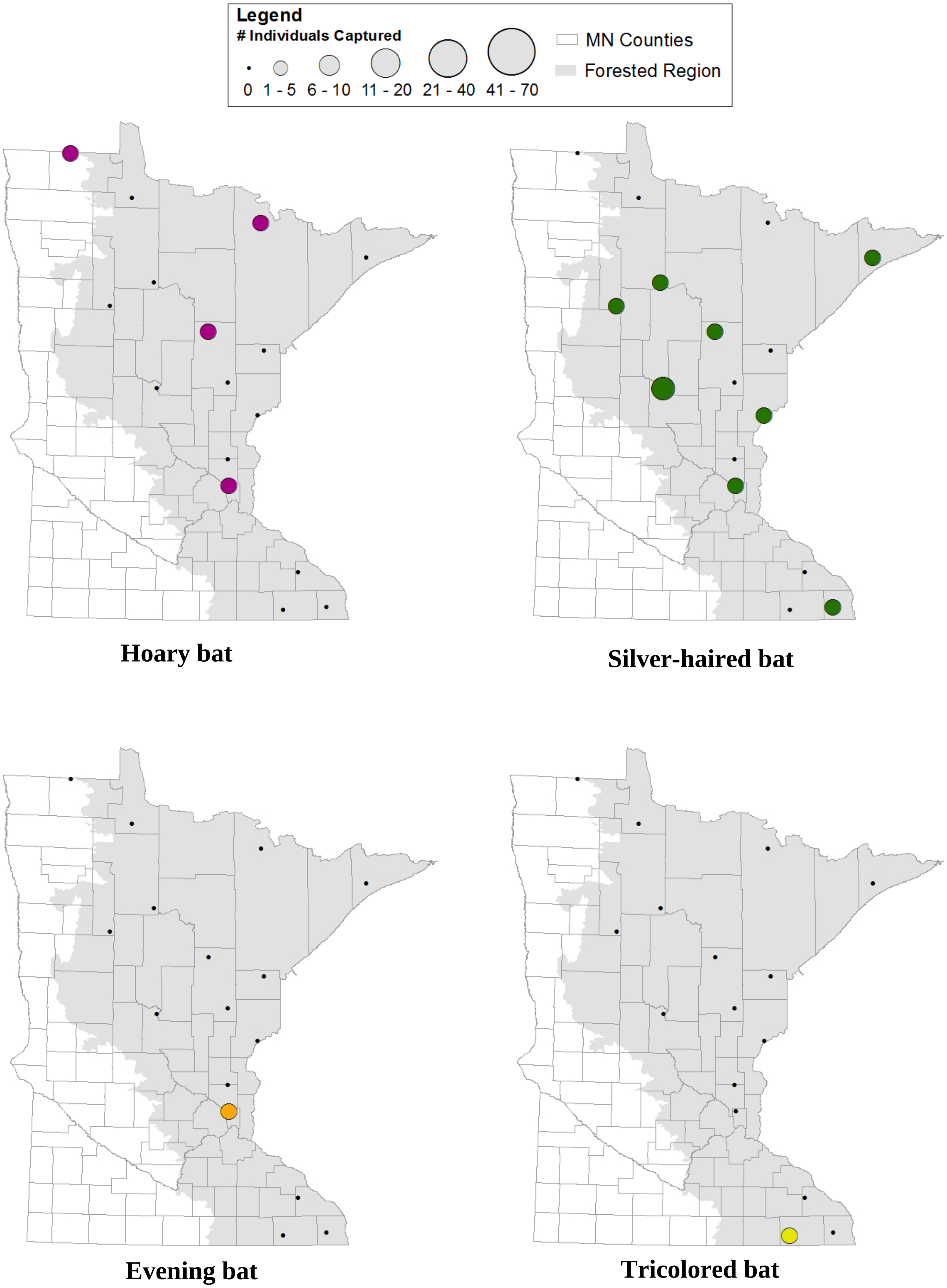


Table 2. Count of bats captured and processed during the 2016 field season by species and sex. EPFU – big brown bat, LABO – eastern red bat, LACI – hoary bat, LANO – silver-haired bat, MYLU – little brown bat, MYSE – northern long-eared bat, NYHU – evening bat, PESU – tricolored bat.

	Species Code								
Sex	**EPFU**	**LABO**	**LACI**	**LANO**	**MYLU**	**MYSE**	**NYHU**	**PESU**	**Total**
Female	76	23	6	12	175	58	1	0	**351**
Male	108	30	1	9	109	37	0	1	**295**
Total	**184**	**53**	**7**	**21**	**284**	**95**	**1**	**1**	**646**

Age and Reproductive Status of Captured Bats

Most bats captured were adults, but 49 juveniles were also captured, with the earliest juvenile captured being an EPFU captured on 7/6/2016 at AHATS. The first juvenile *Myotis* spp. was a MYLU captured on 7/7/2016, also at AHATS. Most captured female bats were pregnant or lactating, with the first lactating bat captured on 6/13/2016 (LACI) at S/HRSF and the first lactating *Myotis* spp. captured on 6/17/2016 at WW (Table 3).

Table 3. Number of individual bats captured of all species by age and reproductive condition by week. P – Pregnant, L – Lactating, TD – Testes descended, NR – Non-reproductive, U – Undetermined. This table only includes those adult bats for which the reproductive assessment had medium or high confidence.

		Adult Female				**Adult Male**			**Juvenile**	**Total Bats**
Week of Capture	**Net-Hours**	**P**	**L**	**NR**	**U**	**TD**	**NR**	**U**	**NR**	
6/6 - 6/12/2016	158	68	0	2	1	5	23	6	0	**105**
6/13 - 6/19/2016	211	58	12	3	1	11	32	6	0	**123**
6/20 - 6/26/2016	162	27	15	10	1	8	36	1	0	**98**
6/27 - 7/3/2016	86	6	18	6	0	4	51	0	0	**85**
7/4 - 7/10/2016	94	0	41	5	0	10	16	1	42	**115**
7/11 - 7/17/2016	136	6	2	4	0	8	14	1	0	**35**
7/18 - 7/23/2016	54	2	4	0	0	2	4	0	7	**19**
Total	**900**	**167**	**92**	**30**	**3**	**48**	**176**	**15**	**49**	**580**

Wing Damage of Capture Bats

Wing scores of 1 or higher were recorded for 276 of the 646 bats captured. The wing damage observed appeared to be consistent with damage caused by WNS, but damage alone does not confirm infection.

Radio-transmittered Bats

We attached transmitters to 45 female MYSE and 3 female MYLU. Of the 45 MYSE, 23 were pregnant at the time of capture, 16 were lactating, 5 were non-reproductive, and the reproductive status of one bat was undetermined. The 3 MYLU were lactating at the time of capture. The 48 bats with transmitters were tracked until the transmitters failed or fell off, which was between 2 – 12 days (median = 6).

Roost Trees

We tracked 42 MYSE and 2 MYLU to their roosts. The MYSE were tracked to 111 unique roost trees of at least 20 species, and one roost in a building (Table 4). The two MYLU were tracked to roosts in two different buildings. For those MYSE which were successfully tracked, we identified an average of 3 roosts per bat.

Table 4. Table of northern long-eared bat roosts identified in 2016 by tree species. Some roost trees were only identifiable to genus due to advanced decay. One additional MYSE roost not listed below was located in a building.

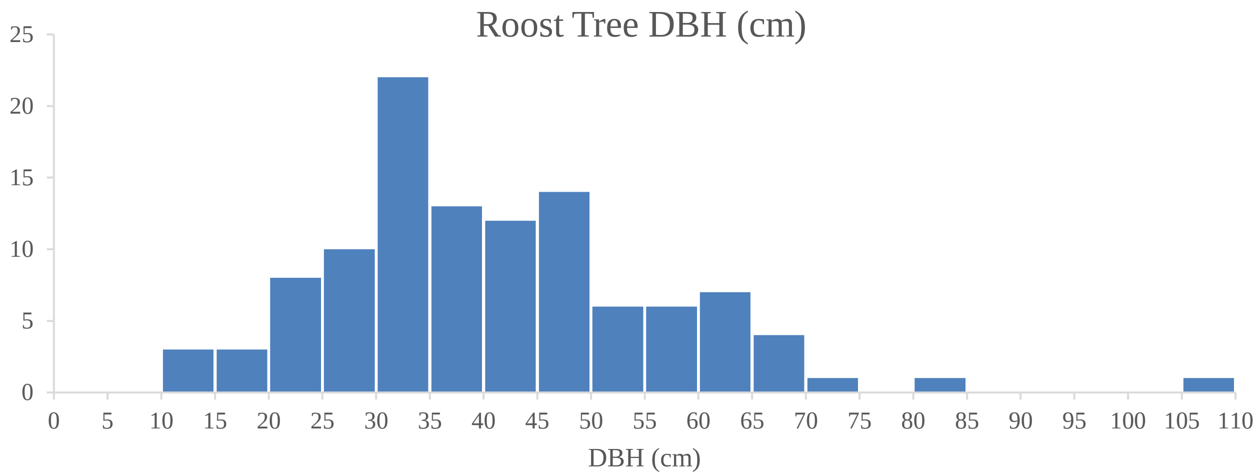
Tree Species Latin Name	**Common Name**	**# of Unique Roosts**	**# Bat-Days[a]**
Populus tremuloides	Quaking/trembling aspen	25	51
Acer rubrum	Red maple	16	45
Quercus rubra/ellipsoidalis[b]	Northern red oak/northern pin oak	13	20
Quercus rubra	Northern red oak	7	9
Betula papyrifera	Paper birch	5	9
Populus grandidentata	Big-tooth aspen	5	7
Tilia americana	American Basswood	5	6
Fraxinus nigra	Black ash	4	4
Fraxinus pennsylvanica	Green ash	4	5
Pinus strobus	White pine	4	6
Ulmus americana	American elm	4	4
Acer saccharum	Sugar maple	3	4
Larix laricina	Tamarack	3	3
Acer spp.	Maple (species unknown)	2	2
Fraxinus spp.	Ash (species unknown)	1	1
Juglans cinerea	Butternut/white walnut	1	1
Juglans nigra	Black walnut	1	2
Pinus resinosa	Red/Norway pine	1	4
Populus balsamifera	Balsam poplar	1	1
Populus spp.	Aspen (species unknown)	1	2
Quercus alba	White oak	1	1
Quercus macrocarpa	Bur oak	1	1
Quercus spp.	Oak (species unknown)	1	1
Robinia pseudoacacia	Black locust	1	1
Thuja occidentalis	Northern white cedar	1	2
	Total:	**111**	**192**

[a] We define one "Bat-Day" as one bat roosting in one tree for one day (only includes days when the transmitter was known to still be attached to the bat).

[b] In some areas where both northern red oak and northern pin oak occur and may hybridize (mainly at CCESR), they were lumped into one category.

The MYSE roost trees varied from 11 – 107 cm in diameter at breast height (DBH), with an average DBH of 41 cm (Fig. 6).

Figure 6. Frequency distribution of the DBH (diameter at breast height) of northern long-eared bat roost trees identified in 2016 (n = 111).



Roosts were located in both live and dead trees of varying decay stage (Fig. 7, Fig. 8). Tree height ranged from 3-30 m (average: 14 m). Crews were unable to measure the height of two roost trees that fell down before characterization.

Figure 7. Histogram showing variation in decay stage among 111 northern long-eared bat roost trees identified in Minnesota in 2016.

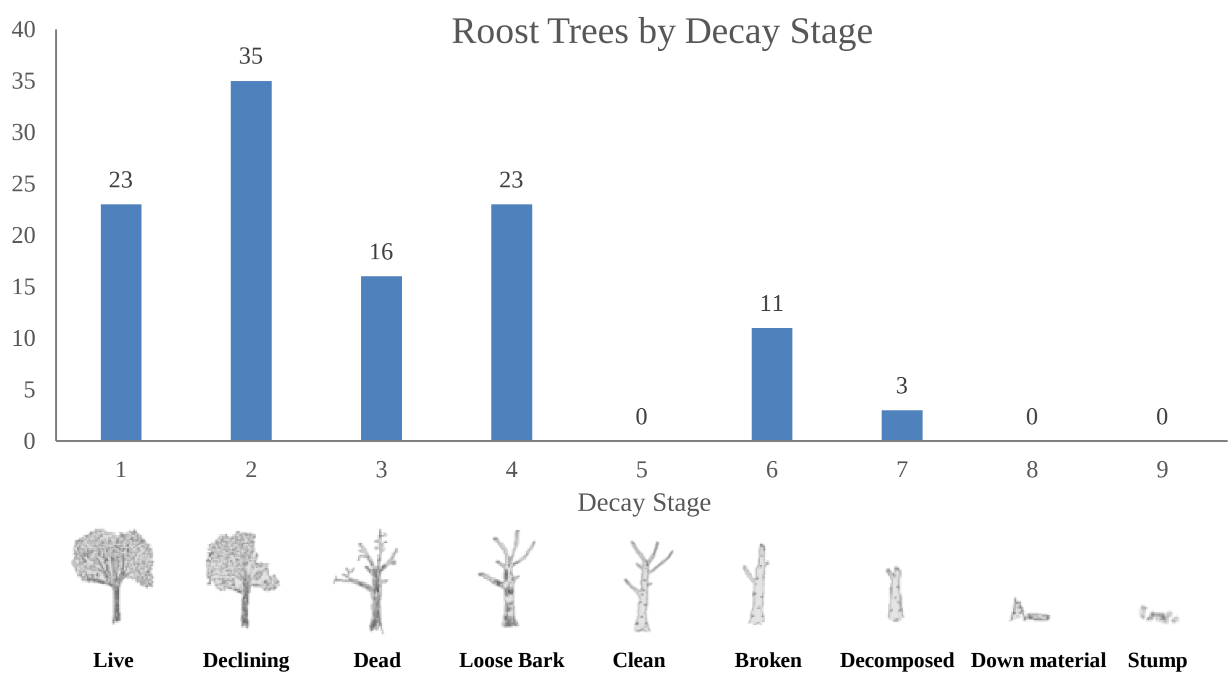


Figure 8. Photos of MYSE roost trees of various species and decay stages identified in 2016. Top row L to R: oak (*Quercus* spp.) snag at CCESR, live bigtooth aspen (*Populus grandidentata*) at ISP, and black ash (*Fraxinus nigra*) snag at S/HRSF. Bottom row L to R: live red maple (*Acer rubrum*) at CCESR, a red maple snag at CCESR, and a black walnut (*Juglans nigra*) snag at Whitewater WMA.

Movements

MYSE with transmitters moved often, spending an average of 1.25 days in each roost (maximum = 4 days), with pregnant bats spending 1.3 days on average, and lactating bats spending 1.1 days on average in each roost (of those roosting events with known start and end dates). Three separate bats with transmitters re-used roosts on non-consecutive days within the tracking period (e.g. moved from roost A on day 1 to roost B on day 2 and then back to roost A on day 3).

The average distance from the capture (foraging) location to the first roost was 589 m, with pregnant bats traveling further to their first roost than lactating bats on average (Table 5). Distance traveled between consecutive roosts was almost always less than 1 km, with 76% of consecutive roosts < 400 m apart.

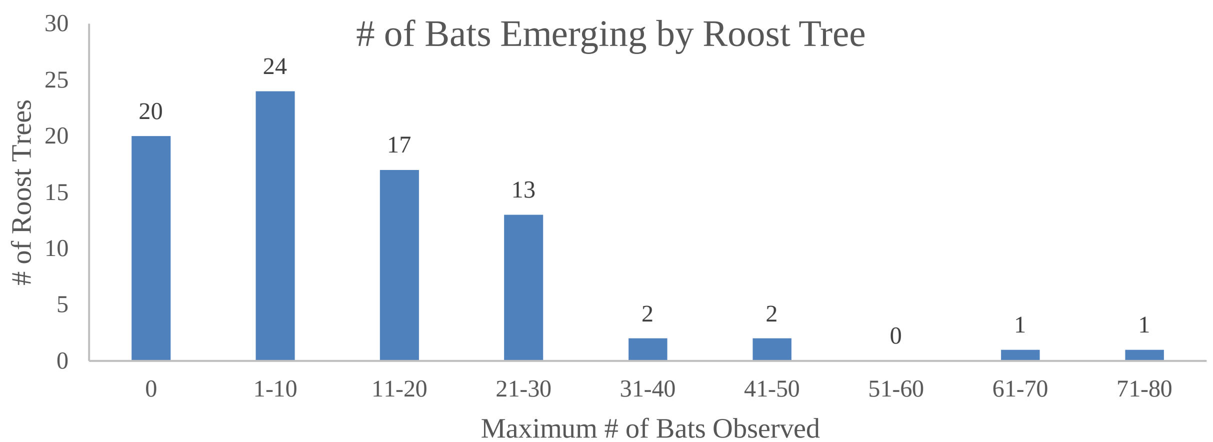
Table 5. Distances traveled (in meters) between roosts and between the capture location and the first roost by northern long-eared bats. Each cell shows the average distance followed by the range in parentheses.

	Pregnant MYSE	**Lactating MYSE**	**All MYSE**
Foraging Area to Roost	716 (24 – 2706)	469 (117 – 1672)	589 (26 – 2706)
Between Consecutive Roosts	341 (7 – 1424)	220 (10 – 669)	309 (7 – 1424)

Emergence Surveys

Field crews conducted 111 emergence surveys on 80 of the identified MYSE roost trees. Bats were observed exiting the tree in 81 of those surveys. Colony size (total count of bats during one survey) ranged from 1 – 71, and averaged 16.4 (Fig. 9). Bats were not observed during 30 surveys, which was due to vegetation obstructing the view, misidentification of the roost tree, weather conditions affecting the emergence behavior of the bats, or the maternity colony having moved to another tree (this sometimes occurred if the transmitter had fallen off of the bat in a previously used roost tree).

Figure 9. Histogram showing the maximum number of bats observed exiting surveyed roost trees during emergence surveys in 2016. If a roost was surveyed multiple times, the maximum number of bats exiting among all surveys is displayed in the figure so that each surveyed roost appears once (n = 80).



Crews also conducted an emergence count on the one building used as a roost by a MYSE. Personnel observed 64 bats emerging from the building during this survey. Five surveys were conducted on the two buildings that were used as roosts by two MYLU, those surveys tallied 297-494 bats emerging.

Discussion

Our project has identified northern long-eared bat roosts in at least 22 species of trees (17 in 2015 and 20 in 2016), including one invasive species (Black locust, *Robinia pseudoacacia*). Roosts are usually located in tree species that are common in a given area, which supports the hypothesis that tree species may not be as important to roost selection as other factors such as availability of cavities, cracks, and loose bark (Boyles 2007, Henderson and Broders 2008). In fact, we have identified MYSE roosts in all of the top ten most common tree species in Minnesota by volume as estimated by the U.S. Forest Service Forest Inventory program (Miles and VanderSchaaf 2015).

Northern long-eared bats switched roosts often in all areas of the state. The average roosting duration in our study (1.25 days) was less than that reported in Randolph County, West Virginia (5.3 d; Menzel et al. 2002) and the Black Hills of South Dakota (3.25 d; Cryan et al. 2001), but similar to that reported in Nova Scotia (1.4 d; Patriquin et al. 2010), Michigan (roughly 2 d, Foster and Kurta 1999), and Tucker County, West Virginia (1.35 d; Johnson et al. 2009). Our reported roosting durations are likely skewed low because the exact duration was almost always unknown for each bat's first and last roosting events.

The average distance moved by northern long-eared bats between consecutive roosts was similar in 2016 (309 m) and 2015 (235 m). Distances between roosts as reported in the literature vary widely, from most being less than 100 m in southern Illinois (Carter and Feldhamer 2005), to an average of 670 meters in Missouri (Timpone et al. 2010). Distances between consecutives roosts varied widely in our study as well (range 7 - 1424 m), but were similar to those reported in Wisconsin in 2015 (average 260 m, range 10 m – 880 m; Wisconsin Department of Natural Resources 2015). Our results suggest that the current 150 ft buffer of restricted tree harvest around known roost trees may not provide protection for many additional roosts. In fact, of the 111 northern long-eared bat roost trees identified during 2016 only 20 (18%) were within 150 ft of another roost tree identified in 2016. Of course our study did not identify all roost trees used by MYSE in a given area, but we did not observe strong "clustering" of roost trees, as has been noted in other studies (e.g. Sasse and Pekins 1996). However, the buffer is likely still beneficial in maintaining the microclimate and forest structure in the area immediately surrounding a known roost tree.

Field crews captured all 7 species of bats known to be residents of the state of Minnesota during 2016. In addition, we recorded the first capture of an evening bat (*Nycticeius humeralis*) in the state (Minnesota Department of Natural Resources 2016b). It is yet unknown if that capture represented a lone individual or a range extension for that species; however, Wisconsin also recently documented their first maternity colony of evening bats along the Illinois border (Wisconsin Department of Natural Resources 2016).

The proportion of bats with wing damage scores ≥ 1 ("light" damage or greater) was similar in 2016 (41.2%) and 2015 (38.3%), although more bats had scores ≥ 2 ("moderate" to "heavy" wing damage) in 2016 (3.4%) than in 2015 (0%). Wing damage does not confirm WNS, but *P. destructans* infection is known to cause lesions and loss of wing tissue (Reichard and Kunz 2009, Cryan et al. 2010). *P.destructans* was first detected in Soudan Underground Mine and Forestville/Mystery Cave State Parks in 2013, with mortalities observed at Soudan Underground Mine in 2016. Widespread population declines generally occur within 3-5 years of WNS being confirmed at a site, and we expect northern long-eared bat populations to decline >90% in the next few years, in addition to declines in populations of the other three cave-roosting bat species (Turner et al. 2011).

Under the Endangered Species Act, there are tree harvest restrictions within 150 ft of known, occupied roost trees in June and July. For more details on these restrictions, please visit the website of the U.S. Fish and Wildlife Service (https://www.fws.gov/Midwest/endangered/mammals/nleb/index.html). We intend to use the data collected in this project to inform future management decisions regarding the northern long-eared bat as WNS continues to spread across the United States.

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NRRI Technical Report – 2017

Summary of 2017 Bat Research in Minnesota

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Report Number: NRRI/TR-201740 Release 1.0

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Summary

Bats were captured at 13 study areas across the forested region of Minnesota during June and July 2017 as part of a statewide project focused on northern long-eared bat habitat use. Northern long-eared bats were listed as threatened under the Endangered Species Act in 2015 due to the impacts of White-Nose Syndrome (WNS). Information about the summer roosts these bats use to raise their young will be used to inform future management decisions. Three-hundred fifty bats were captured over 57 nights of mist-netting. Due to low capture rates of northern long-eared bats, VHF transmitters were deployed on adult little brown and big brown bats in addition to northern long-eared bats. We tracked 37 bats to their roosts in 81 trees and six buildings. All bat species roosted in trees of multiple species, varying size, and different decay stages. Colony size ranged from 1 – 45 at tree roosts and from 2 – 450 at building roosts. Fewer northern long-eared bats were captured in 2017 than in previous years, and colony size at northern long-eared bat roosts was also lower than in previous years. These declines are likely the results of WNS mortality. A report summarizing all years of this project (2015 – 2017) will be available in 2018.

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Please contact authors before citing as manuscripts are in review and in preparation

This report and any future releases or corrections will be available online from the University Digital Conservancy (https://conservancy.umn.edu)

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Introduction

White-nose syndrome (WNS) is a fungal disease that has devastated bat populations in the eastern United States, where it was first observed in 2006. WNS has since spread westward, killing more than 5 million bats by 2012 (U.S. Fish and Wildlife Service 2012). The fungus that causes WNS, *Pseudogymnoascus destructans*, thrives in cold humid environments such as the caves and mines that some bats use for hibernation. Bats that are infected with WNS awake more often during hibernation, use up their fat reserves, and then often die of either starvation or exposure to the elements as they search for food in late winter (Frick et al. 2010). In 2013, the fungus that causes WNS was first detected in Minnesota at Soudan Underground Mine, and the first bat mortalities from WNS were observed during the winter of 2015/2016 (Minnesota Department of Natural Resources 2013, 2016).

Eight species of bats have been documented in Minnesota: little brown bats (*Myotis lucifugus*, MYLU), northern long-eared bats (*Myotis septentrionalis*, MYSE), big brown bats (*Eptesicus fuscus*, EPFU), tricolored bats (*Perimyotis subflavus*, PESU), silver-haired bats (*Lasionycteris noctivagans*, LANO), eastern red bats (*Lasiurus borealis*, LABO), hoary bats (*Lasiurus cinereus*, LACI), and evening bats (*Nycticeius humeralis*, NYHU). Four of Minnesota's bat species hibernate in caves and mines and can be affected by WNS: MYSE, MYLU, EPFU, and PESU. The northern long-eared bat experienced especially high mortality rates from WNS in the northeastern U.S., which led to its listing as threatened under the Endangered Species Act in 2015.

In response to this listing, the Minnesota Department of Natural Resources (MN DNR), University of Minnesota Duluth – Natural Resources Research Institute (NRRI), and U.S. Forest Service (USFS), began collaboration in 2015 on a statewide project to study northern long-eared bat summer habitat use, funded by the Environment and Natural Resources Trust Fund (ENRTF). Northern long-eared bats hibernate during the winter, but disperse across the forested region of the state during the summer, foraging on insects at night and roosting in trees during the day. Female bats also give birth and raise their young in these summer roosts, making information on roost selection critical to maintaining high-quality habitat for reproduction.

Data for this project were collected from across the state in 2015 – 2017, including 13 sites in 2017. Results from previous years were summarized in technical reports (Swingen et al. 2015, 2016), and a forthcoming report will summarize results from the entire project (2015-2017). This report summarizes the results from the 2017 field season of the ENRTF-funded project, with support from additional funding sources.

Methods

Bat Capture/Processing

Field crews set up fine mesh mist-nets (Avinet Inc, Dryden, NY, USA) along forested roads, trails, streams, etc. that could act as travel corridors for bats. Each night, 2 – 4 mist-nets were set up within 200 m of a central processing location. We opened mist-nets after sunset, and checked them every 15 minutes for 2 – 5 hours, depending on capture rates and weather conditions.

We identified each captured bat to species, and determined sex, age, and reproductive condition by physical examination. Each bat was also weighed and measured, and the wings were inspected for damage potentially caused by white-nose syndrome (Fig. 1). Wing condition was scored from 0 – 3 according to the Reichard wing-damage index, where 0 indicates no damage and 3 indicates severe damage (Reichard and Kunz 2009). We then fitted each bat with an individually-numbered lipped aluminum wing band (Porzana Ltd., Icklesham, United Kingdom).

Figure 1. Photos showing the techniques for capturing and processing bats. Photo Credits: A – Superior National Forest; B – Brian Houck, NRRI; C – Peter Kienzler, NRRI, D – Christi Spak, MN DNR; E – Ryan Pennesi, USFS; F – Nancy Dietz, MN DNR - CRTC.

A: Mist-nets are raised on poles with a pulley system

B: A bat flies into the mist-net and is caught

C: Bats are handled with disposable nitrile gloves to prevent spread of WNS between bats

D: The wings are examined for damage consistent with WNS

E: A numbered band is attached to the forearm

F: A small transmitter is glued to the skin of the bat using surgical adhesive

Field crews attached radiotransmitters (A2414 Advanced Telemetry Systems Inc., Isanti, MN; or LB-2X, Holohil Systems Ltd., Carp, ON, Canada) to selected adult bats. At the beginning of the summer, we limited transmitter attachment to adult female northern long-eared bats and added other species and sexes later in the season as we assessed capture success. We trimmed a section of hair in the center of the back, and used surgical adhesive (Perma-Type, Permatype Company Inc., Plainville, CT, USA) to attach the transmitter to the skin (Fig. 1). We released all bats at the capture site after processing.

Tracking/Roost Tree Characterization

We tracked bats with radiotransmitters daily to their roosts using radio telemetry until the transmitter failed or fell off. Data recorded at each roost included roost type, tree species, and decay stage. At dusk, crews returned to the roost trees to conduct emergence surveys. During an emergence survey, personnel watched the roost tree from 30 minutes before sunset to 1 hour after sunset. During the survey we recorded the number of bats emerging during each 10-minute interval, the location of the exit point, and whether or not the transmitter left the tree.

Crews returned to each roost tree to conduct a more detailed tree characterization after bats left. This included measuring roost diameter at breast height (dbh), tree height, decay stage, canopy closure, slope, aspect, and recording details about the vegetation surrounding the roost tree.

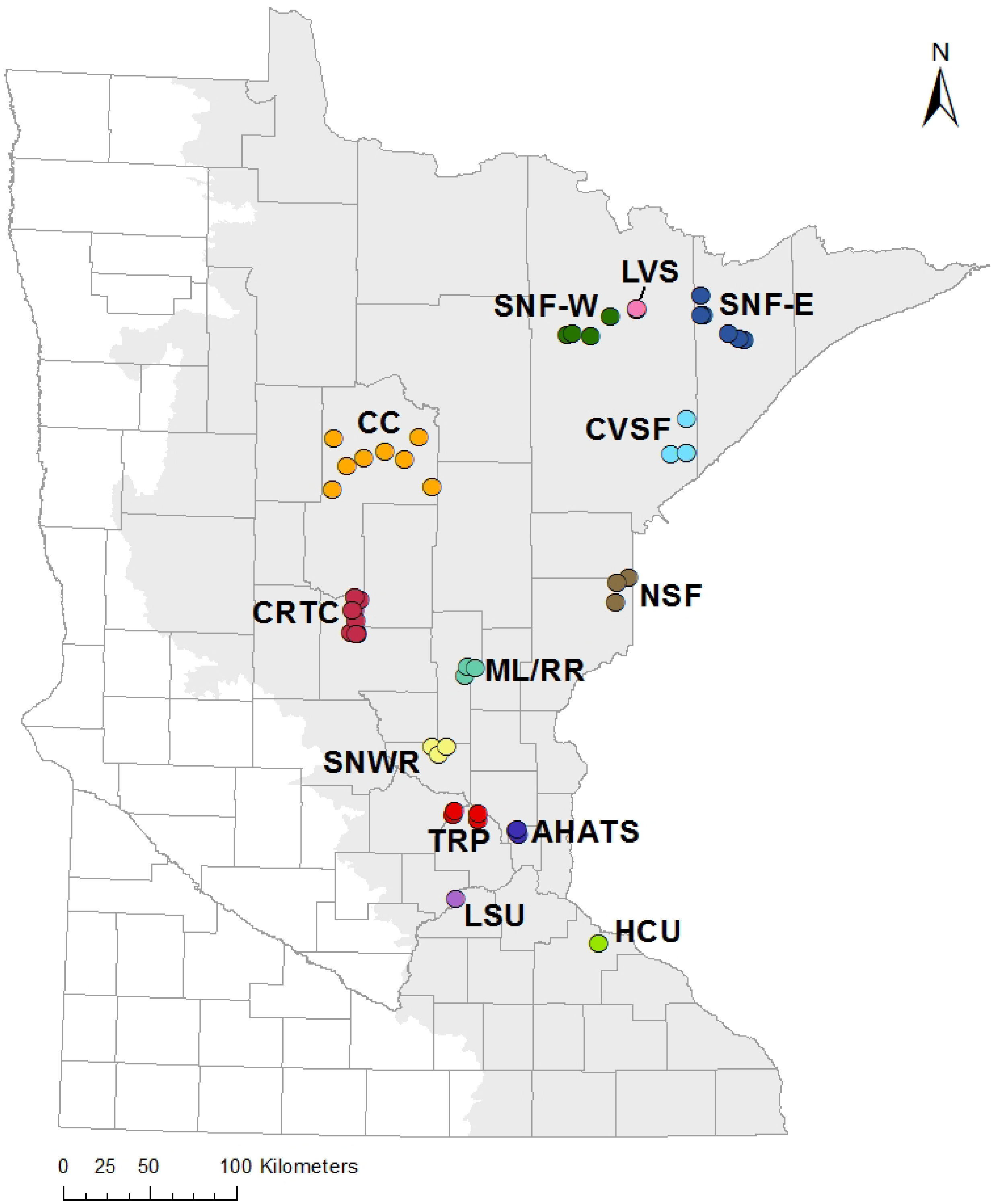
Study Area

We captured bats with mist-nets at 53 sites grouped into 13 study areas throughout the forested region of the state of Minnesota (Table 1, Fig. 2).

Table 1. Names and abbreviations of study areas and dates during which bat mist-netting took place during the 2017 field season.

Study Area Name	Abbreviation	MN County(ies)	Ownership	Date Range
Arden Hills Army Training Site	AHATS	Ramsey	Federal	7/5 – 7/8
Camp Ripley Training Center	CRTC	Morrison	State	6/5 – 6/26
Cass County Sites – Chippewa National Forest, Cass County Forest, & Land O'Lakes State Forest	CC	Cass	County	7/17 – 7/26
Cloquet Valley State Forest	CVSF	St. Louis	State/County	6/5 – 6/8
Hay Creek Unit – Richard J. Dorer State Forest	HCU	Goodhue	State	6/5 – 6/6
Lake Vermilion – Soudan Underground Mine State Park	LVS	St. Louis	State	6/20 – 6/22
Louisville Swamp Unit – Minnesota Valley National Wildlife Refuge	LSU	Scott	Federal	6/19
Mille Lacs Wildlife Management Area/Rum River State Forest	ML/RR	Mille Lacs, Kannabec	State	6/12 – 6/15
Nemadji State Forest	NSF	Pine	State	7/18 – 7/20
Sherburne National Wildlife Refuge	SNWR	Sherburne	Federal	7/5 – 7/8
Three Rivers Park District – Crow-Hassan and Elm Creek Park Reserves	TRP	Hennepin	Three Rivers Park District	6/25 – 6/28
Superior National Forest – West (Laurentian Ranger District)	SNF-W	St. Louis	Federal	6/19 – 6/29
Superior National Forest – East (Kawishiwi and Tofte Ranger Districts)	SNF-E	Lake	Federal	6/12 – 7/13

Figure 2. Map of all 2017 mist-netting locations within the forested region (shaded) of Minnesota. Each dot represents a separate mist-netting site. Mist-netting sites were grouped into "study areas" and are labeled with abbrevations as listed in Table 1.



Results

Mist-Netting

We conducted 57 nights of mist-netting between June 5th and July 27th, 2017, with multiple crews operating simultaneously across the state. Mist-netting took place for 1 – 9 nights at each study area.

Species Captured

We captured and processed 350 bats over 817 net-hours (Fig. 3). We captured individuals of six of the eight bat species recorded in Minnesota (Fig. 4, Table 2). Tricolored bats and evening bats were not captured in 2017.

Figure 3. Map of bat mist-netting capture results in 2017 for all species. Capture results are displayed by study area as listed in Table 1. The size of the symbol at each study area represents the total capture rate (bats/net-hour), and the label at each study area indicates the total number of individuals captured. Note that the high capture rate at one site in St. Louis County was likely due to the proximity to Soudan Mine (within 1 km of mine entrances), which is the largest known hibernaculum in the state.

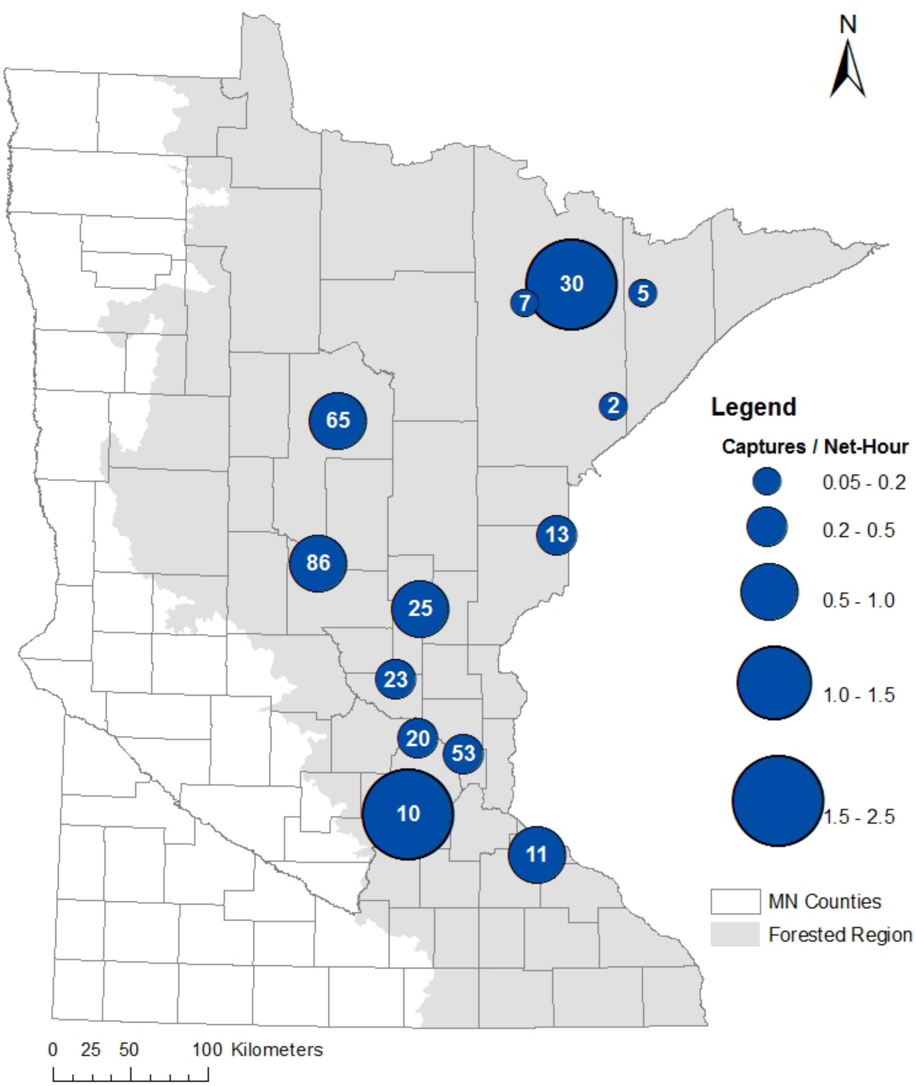


Figure 4. Maps of bat mist-netting results (captures per 10 net-hours) by species in 2017. Capture results are displayed by study area as shown in Figure 2 and listed in Table 1. See Table 2 for total captures by species.

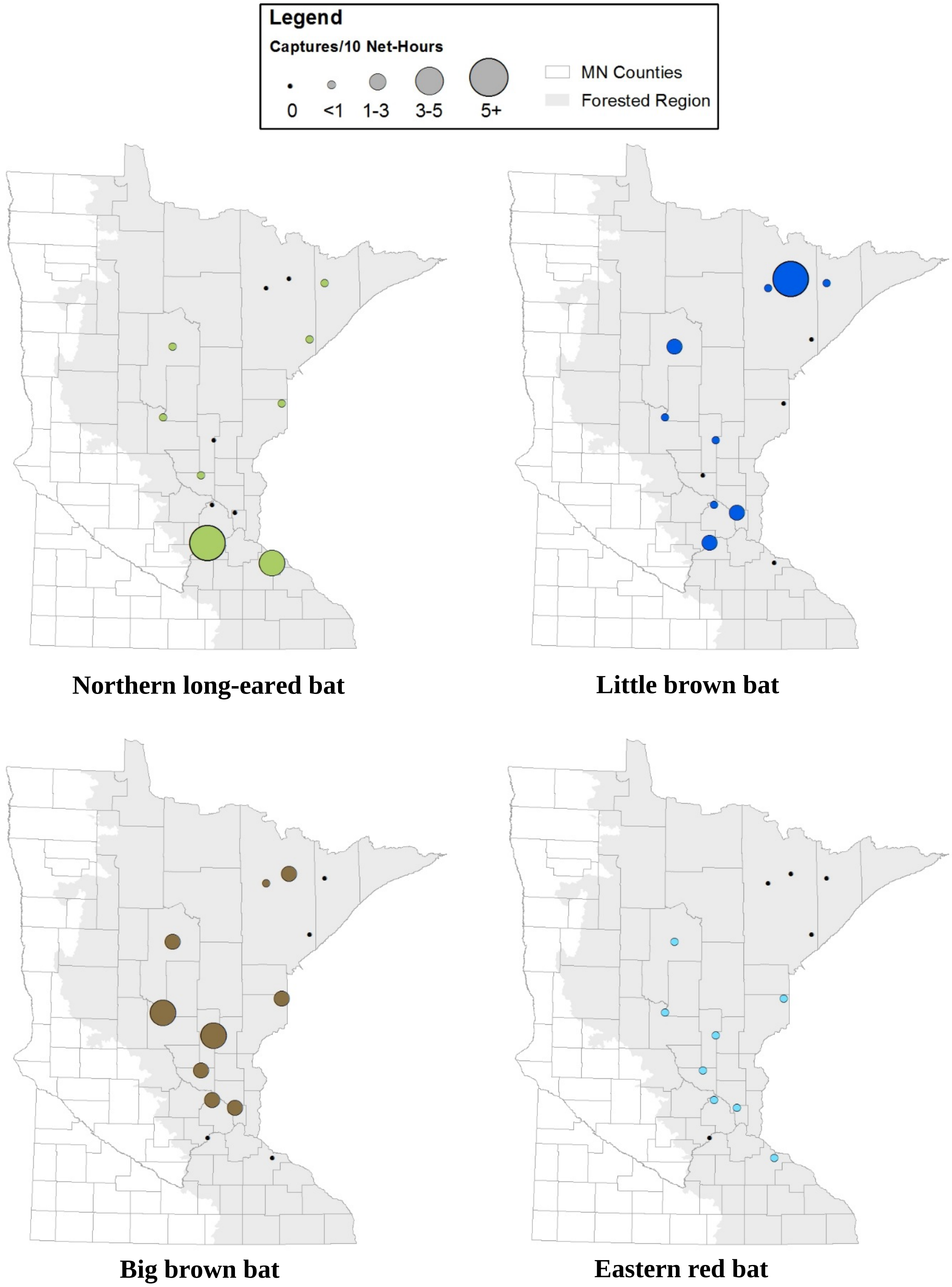


Figure 4 (cont.) Maps of bat mist-netting results (captures per 10 net-hours) by species in 2017. Capture results are displayed by study area shown in Figure 2 and listed in Table 1. See Table 2 for total captures by species.

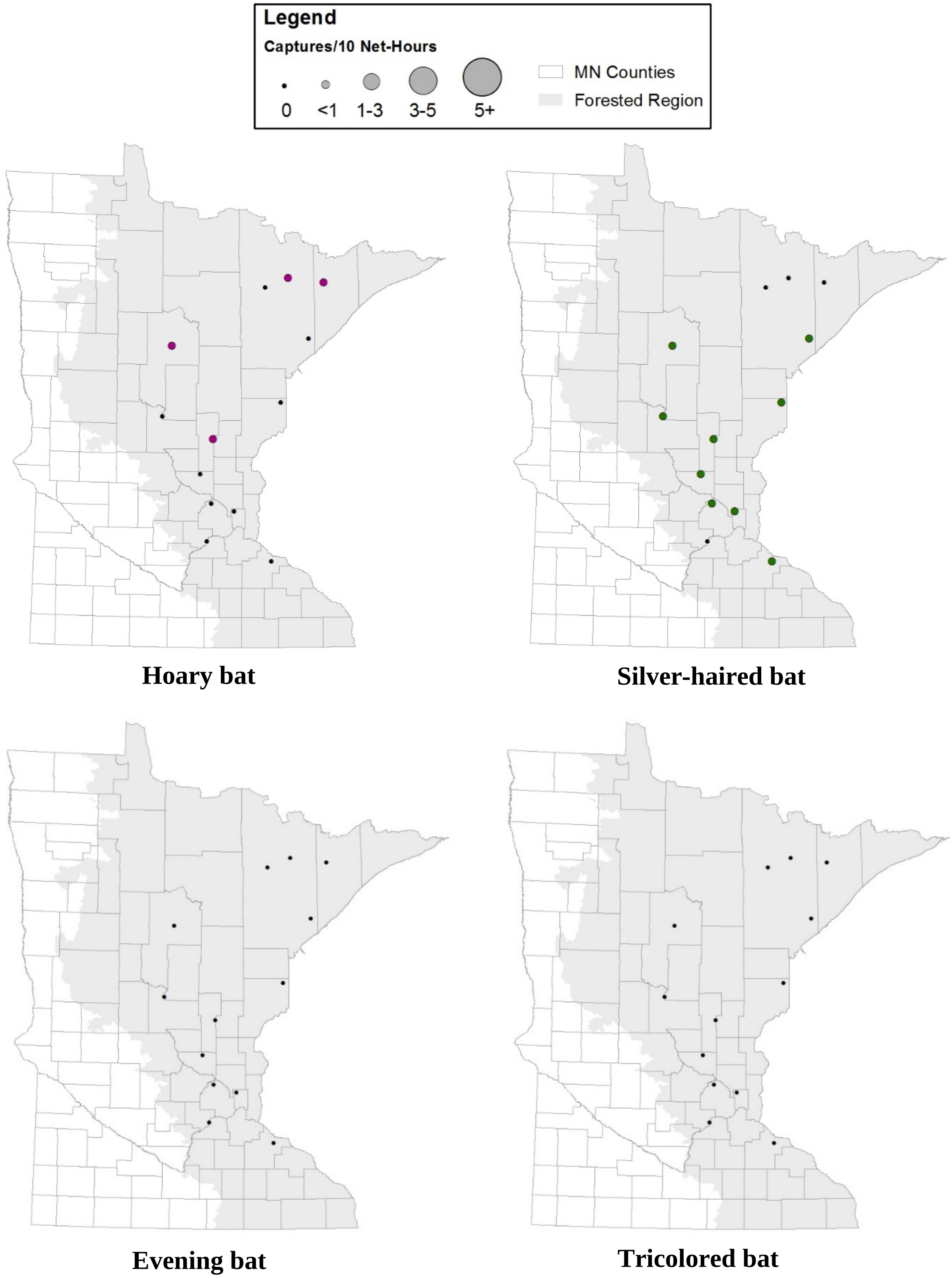


Table 2. Count of bats captured and processed during the 2017 field season by species and sex. EPFU – big brown bat, LABO – eastern red bat, LACI – hoary bat, LANO – silver-haired bat, MYLU – little brown bat, MYSE – northern long-eared bat, NYHU – evening bat, PESU – tricolored bat.

	Species Code								
Sex	**EPFU**	**LABO**	**LACI**	**LANO**	**MYLU**	**MYSE**	**NYHU**	**PESU**	**Total**
Female	73	21	1	25	35	24	0	0	**179**
Male	83	12	3	12	53	8	0	0	**171**
Total	**156**	**33**	**4**	**37**	**88**	**32**	**0**	**0**	**350**

Age Class and Reproductive Status of Captured Bats

Most bats captured were adults, but 46 juveniles were also captured, with the earliest juveniles captured (EPFU and LANO) on July 5th at AHATS. The first juvenile *Myotis* spp. was a MYLU captured on July 6th at AHATS. Most captured female bats were pregnant or lactating, with the first lactating bat captured on June 13th (EPFU) at CRTC and the first lactating *Myotis* spp. captured on June 20th at LVS (Table 3).

Table 3. Number of individual bats captured of all species by age and reproductive condition by week. P – Pregnant, L – Lactating, PL – Post-lactating, TD – Testes descended, NR – Non-reproductive, U – Undetermined. This table only includes those bats for which the reproductive assessment had medium or high confidence.

		Adult Female					**Adult Male**			**Juvenile**	**Total Bats**
Week of Capture	**Net-Hours**	**P**	**L**	**PL**	**NR**	**U**	**TD**	**NR**	**U**	**NR**	
6/5 – 6/11	137	28	0	0	0	6	1	17	3	0	**55**
6/12 – 6/18	104	16	2	0	2	0	1	22	0	0	**43**
6/19 – 6/25	102	7	11	0	2	6	1	28	3	0	**58**
6/26 – 7/2	108	6	11	0	2	0	1	16	0	0	**36**
7/3 – 7/9	178	6	28	0	1	1	3	13	0	23	**75**
7/10 – 7/16	37	0	0	0	0	0	0	2	0	0	**2**
7/17 – 7/23	97	4	3	5	2	0	5	9	0	8	**36**
7/24 – 7/28	56	0	3	2	2	0	9	8	0	14	**38**
Total	**817**	**67**	**58**	**7**	**11**	**13**	**21**	**115**	**6**	**45**	**343**

Wing Damage of Captured Bats

Wing scores of 1 or higher were recorded for 238 of the 350 bats captured (68%), including individuals of all six species captured. Moderate (wing score = 2) damage was recorded for 7% of cave-hibernating bats (EPFU, MYLU, & MYSE) captured, but only one bat showed severe (wing score = 3) damage. The moderate and severe wing damage we observed was likely caused by WNS, although damage alone does not confirm infection.

Radiotransmittered Bats

Our original goal was to deploy transmitters only on reproductive female MYSE, but due to low capture rates in 2017 we began attaching transmitters to female and male MYSE, MYLU, and EPFU. We attached transmitters to 44 bats, including 20 female MYSE (Table 4). The bats were tracked until the transmitters failed or fell off, which was between 1 – 31 days (median = 6).

Table 4. Count of bats which were given transmitters in 2017 by species, sex, and reproductive condition. EPFU – big brown bat, MYLU – little brown bat, MYSE – northern long-eared bat.

		Species Code			
Sex	**Reproductive Condition**	**EPFU**	**MYLU**	**MYSE**	**Total**
Female	Pregnant	3	4	7	14
	Lactating	4	5	3	12
	Post-Lactating	1	0	1	2
	Non-Reproductive	0	2	1	3
	Undetermined	0	0	8	8
Male	Testes Descended	0	0	2	2
	Non-Reproductive	1	2	0	3
Total		**9**	**13**	**22**	**44**

Roost Trees

We tracked 19 MYSE, 10 MYLU, and 8 EPFU to their roosts in 81 trees and six buildings. Seven of the bats originally given transmitters could not be relocated after release. The 19 MYSE were tracked to 56 unique roost trees of at least 17 species (advanced decay of some trees did not allow for identification to species), and one roost in a building. The 10 MYLU were tracked to 12 roost trees of at least four species, and three roosts in buildings. The eight EPFU were tracked to 13 roost trees of at least seven species, and two roosts in buildings. See Appendix A for a full list of tree species used as roost trees in 2017. All bats with transmitters that roosted in buildings were females. For those bats which were tracked to at least one roost, we identified an average of 2.8 roosts per bat.

The roost trees varied from 12 – 72 cm in diameter at breast height (DBH), with an average DBH of 38 cm (Table 5, Fig. 5). Roosts were located in both live trees and dead trees of varying decay stage (Figs. 6,7,8,9). Roost tree height ranged from 4 – 30 m (average 15 m).

Table 5. Characteristics of tree roosts used by bats in 2017, by bat species and sex. Each cell shows the average value followed by the range in parentheses (if applicable). N = number of roost trees identified.

Bat Species/Sex	**N**	**DBH (cm)**	**Decay Class**	**Height (m)**
EPFU / Female	12	34.7 (13.6 – 53.0)	3.6 (1 – 7)	14.4 (4.6 – 21.8)
EPFU / Male	1	51.8	2.0	23.6
MYLU / Female	5	41.3 (24.3 – 66.0)	1.8 (1 – 2)	13.8 (7.2 – 18.6)
MYLU / Male	7	25.4 (16.3 – 37.2)	4.6 (1 – 6)	10.0 (6.0 – 15.2)
MYSE / Female	53	39.3 (11.5 – 71.9)	2.7 (1 – 7)	16.7 (3.8 – 30.5)
MYSE / Male	3	34.2 (32.8 – 35.3)	3.3 (1 – 6)	6.7 (4.9 – 9.5)
Overall	**81**	**37.5 (11.5 – 71.9)**	**2.95 (1 – 7)**	**15.3 (3.8 – 30.5)**

Figure 5. Frequency distribution of the DBH (diameter at breast height) of bat roost trees identified in 2017 (n = 81).

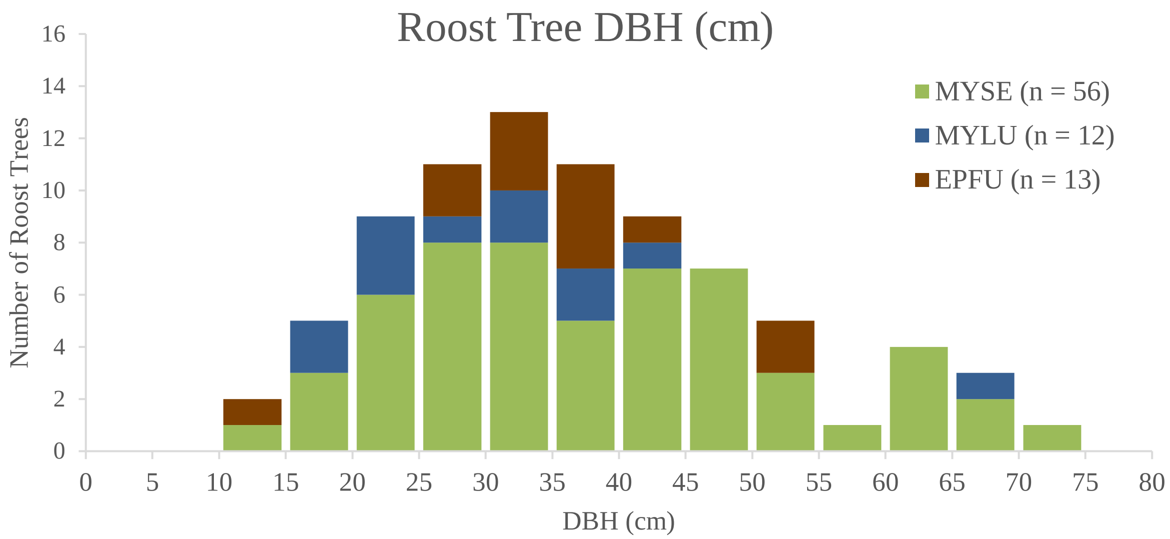


Figure 6. Histogram showing the decay stage of 81 bat roost trees identified in Minnesota in 2017.

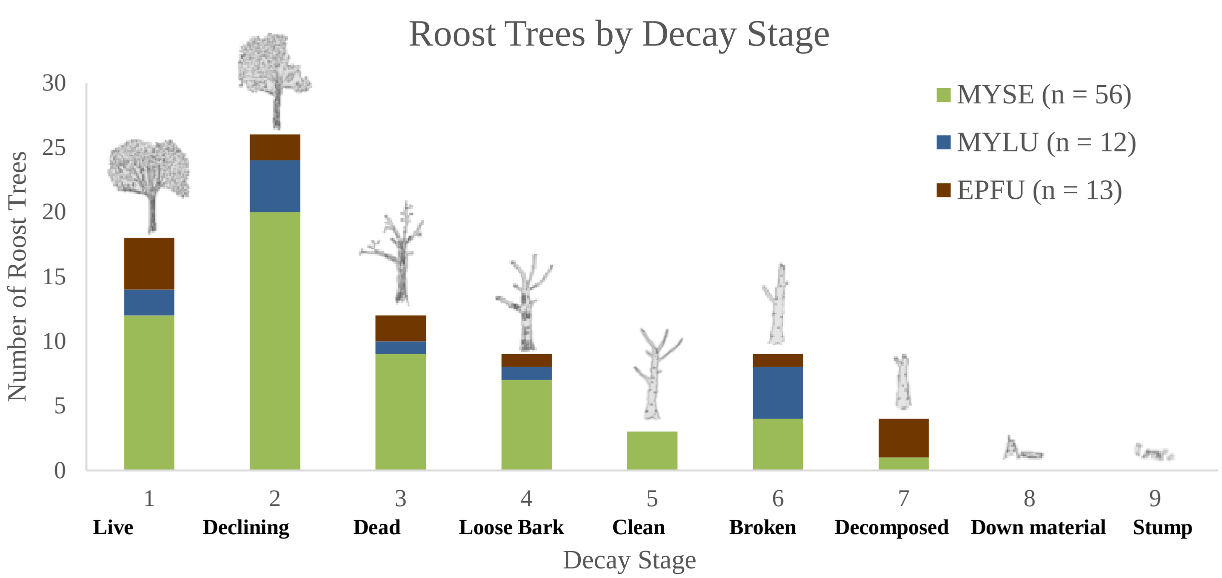


Figure 7. Photos of female northern long-eared bat roost trees identified in 2017. Top row left to right: American elm (*Ulmus americana)* snag in Hay Creek Unit, live paper birch (*Betula papyrifera*) at Camp Ripley Training Center, green ash (*Fraxinus pennsylvanica*) snag at Camp Ripley Training Center, live red pine (*Pinus resinosa*) at Camp Ripley Training Center, live trembling aspen (*Populus tremuloides*) in Cloquet Valley State Forest, and live sugar maple (*Acer saccharum*) in Hay Creek Unit.

Figure 8. Photos of big brown bat roost trees of various species and decay stages identified in 2017. From left to right: bigtooth aspen (*Populus grandidentata*) snag in the Chippewa National Forest, live red cedar (*Juniperus virginiana*) in Three Rivers Park District, and bur oak (*Quercus macrocarpa*) snag on Cass County land.

Figure 9. Photos of little brown bat roosts of various species and decay stages identified in 2017. From left to right: *Populus* spp. snag in the Superior National Forest, live green ash (*Fraxinus pennsylvanica*) in Three Rivers Park District, and trembling aspen (*Populus tremuloides*) snag with broken/hanging top in the Chippewa National Forest.

Movements

The 18 female MYSE that were successfully tracked spent an average of 1.5 days (maximum = 5 days) in each roost (of those roosting events with known start and end dates, n =33). Female big brown bats spent an average of 1.3 days in each roost (n = 7 roosting events of known length), and male little brown bats spent an average of 1.6 days in each roost (n = 18 roosting events of known length). There were less than three roosting events of known length for male big brown bats, female little brown bats, and male northern long-eared bats.

The average distance from the capture (foraging) location to the first roost for all bats was 922 m, and was similar for females (936 m) and males (809 m). EPFU traveled farther on average than MYLU and MYSE from the capture location to their first roost (Table 6). Distance traveled between consecutive roosts for all bats averaged 296 m, with 80% of consecutive roosts < 500 m apart. A male MYSE had the farthest recorded distance between consecutive roosts at 2193 m (Table 7). Three bats with transmitters (one male MYLU, one MYLU female, and one EPFU female) re-used roosts on non-consecutive days within the tracking period (e.g. moved from roost A on day 1 to roost B on day 2 and then back to roost A on day 3).

Table 6. Distances traveled (in meters) between the capture location and the first roost by bats with radiotransmitters in 2017. Each cell shows the average distance followed by the range in parentheses.

Sex	EPFU	MYLU	MYSE	Overall Average
Female	1456 (565 – 3234)	1160 (259 – 2199)	635 (80 – 1380)	936 (80 – 3234)
Male	684	1246 (232 – 2261)	59	809 (59 – 2261)
Overall Average	1360 (565 – 3234)	1177 (232 – 2261)	604 (59 – 1380)	922 (59 – 3234)

Table 7. Distances traveled (in meters) between consecutive roosts by bats with radiotransmitters in 2017. Each cell shows the average distance followed by the range in parentheses.

Sex	EPFU	MYLU	MYSE	Overall Average
Female	317 (33 – 555)	36 (4 – 101)	300 (2 – 1013)	290 (2 – 1013)
Male	-	244 (14 – 416)	739 (12 – 2193)	314 (12 – 2193)
Overall Average	317 (33 – 555)	214 (4 – 416)	325 (2 – 2193)	296 (2 – 2193)

Emergence Surveys

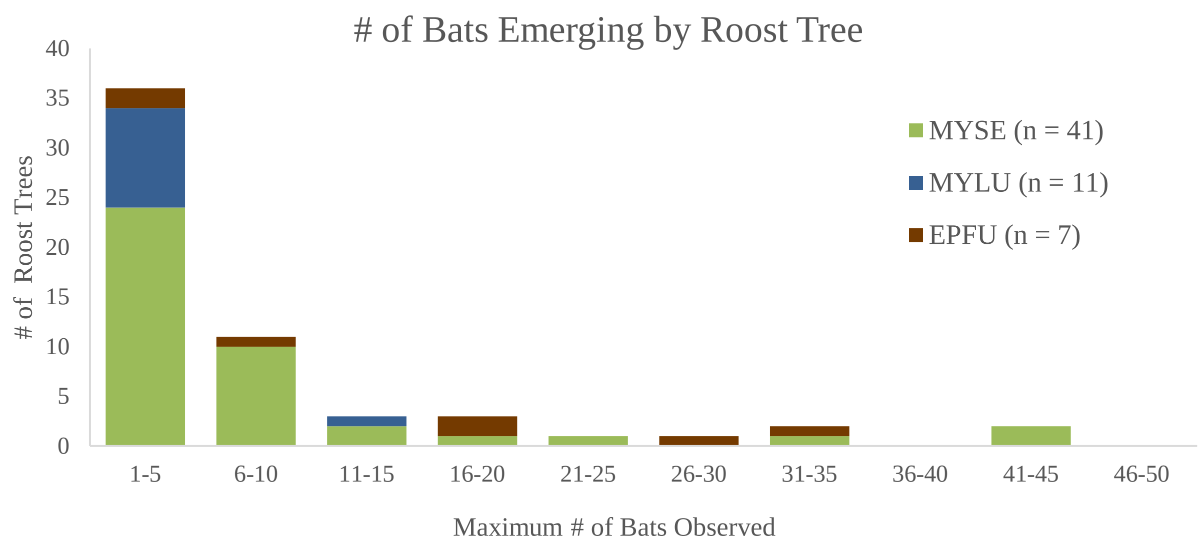
Field crews conducted 70 emergence surveys on 46 of the identified female northern long-eared bat roost trees. Bats were observed exiting the roost in 59 of those surveys. Colony size (total count of bats during one survey) at female northern long-eared bat tree roosts ranged from 1 – 45 and averaged 6.9 (Table 8). Bats were not observed at seven female northern long-eared bat roost trees, which was due to vegetation obstructing the view, misidentification of the roost tree, weather conditions affecting the emergence behavior of the bats, or the maternity colony having moved to another tree (this sometimes occurred if the transmitter had fallen off of the bat in a previously used roost tree).

We also conducted emergence surveys at 23 other identified roost trees used by male northern long-eared bats, and male and female little brown bats and big brown bats. Colony size at roost trees used by female bats was greater on average than colony size at roost trees used by male bats (Table 8).

Table 8. Emergence survey results at tree roosts surveyed in 2017, by bat species and sex. If a roost was surveyed multiple times, the maximum number of bats exiting among all surveys was used to calculate the average colony size across trees. Colony sizes reported here are only for those trees at which bats were observed during emergence surveys (n = 59). Building roosts were not included for this table.

Bat Species	Bat Sex	# Total Surveys	# Roosts Surveyed	# Roosts with Bat Observations	Minimum Colony Size	Maximum Colony Size	Mean Colony Size
MYSE	F	70	46	39	1	45	8.2
MYSE	M	5	3	2	1	3	2.0
MYLU	F	9	4	4	2	13	5.5
MYLU	M	12	7	7	1	5	1.6
EPFU	F	9	8	7	2	34	16.1
EPFU	M	1	1	0	-	-	-

Figure 10. Maximum number of bats observed exiting surveyed roost trees in 2017. If a roost was surveyed multiple times, the maximum number of bats exiting among all surveys is displayed in the figure so that each surveyed roost tree at which bats were observed appears once (n = 59). Emergence counts at roosts in buildings are not included in this chart.



We conducted three surveys of the one building used as a roost by a female northern long-eared bat and observed 3 – 5 bats emerging. At the three buildings used as roosts by female little brown bats, crews observed between 2 – 480 emerging (average = 183). At the two buildings used as roosts by big brown bats, we observed 44 – 96 bats emerging (average = 70).

Discussion

Northern long-eared bat capture rates in 2017 (0.04 bats/net-hour) were lower than capture rates for MYSE in 2016 (0.11) and 2015 (0.15). Average colony size at female MYSE roost trees (8.2) was lower than in previous years as well (2016 = 16.4, 2015 = 21.5). Although many factors can influence capture rates, we suspect these declines are primarily a result of mortality from WNS observed during the winters of 2015/2016 and 2016/2017 (Minnesota Department of Natural Resources 2016, 2017). At the Soudan Underground Mine, which is the largest known hibernaculum in the state, winter counts of hibernating bats in early 2017 were down 73% from the previous year (Minnesota Department of Natural Resources 2017). Also noteworthy was that zero northern long-eared bats were observed during 2016/2017 winter surveys of the Soudan Underground Mine (G. Nordquist, pers. comm.).

The proportion of bats with wing damage scores ≥ 1 (“light” damage or greater) was also greater in 2017 (68%) than in 2015 and 2016 (38% and 41%, respectively). Wing damage does not confirm WNS, but *P. destructans* infection is known to cause lesions and loss of wing tissue (Reichard and Kunz 2009, Cryan et al. 2010). Thirty-six of the 238 bats with wing damage scores ≥ 1 were migratory species (LABO, LACI and LANO) not known to be affected by WNS, although none of these bats were given wing scores of 2 or 3. Minor wing damage in migratory bats unrelated to WNS has also been observed in the eastern U.S. and highlights the importance of lab testing to confirm WNS infection (Francl et al. 2011). Results are pending from laboratory tests of swabs collected from a subset of bats captured in this project.

Our 2017 field season added 5 new tree species to the existing list of tree species used as roosts by female northern long-eared bats, now totaling 27 species. New tree species documented as roosts in 2017 included box elder (*Acer negundo*), silver maple (*Acer saccharinum*), hackberry (*Celtis occidentalis*), black cherry (*Prunus serotina*), and northern pin oak (*Quercus ellipsoidalis*). This lends greater support to the hypothesis that tree species may not be as important to roost selection as other factors such as availability of cavities, cracks, and loose bark (Boyles 2007, Henderson and Broders 2008).

As observed in past years, female northern long-eared bats switched roosts often. The average roosting duration in 2017 (1.45 days) was similar to that observed in 2015 and 2016 (1.33 and 1.25 days, respectively). These durations are also similar to roosting durations reported in Nova Scotia, Michigan, and West Virginia (Foster and Kurta 1999, Johnson et al. 2009, Patriquin et al. 2010), but shorter than durations reported in West Virginia and the Black Hills of South Dakota (Cryan et al. 2001, Menzel et al. 2002).

The 2017 season also allowed us to collect roosting data from other bats that can be affected by WNS, including male MYSE, and male and female MYLU and EPFU. We did not observe strong preferences in any of these groups for certain tree species, tree sizes, or decay classes although sample size was small. EPFU and MYLU tended to roost in cavities and crevices, as observed in other studies (e.g. Brigham 1991, Kalcounis and Brigham 1998, Agosta 2002, Broders and Forbes 2004, Fabianek et al. 2015). MYSE also roosted in cavities and crevices, as well as under loose bark, which has been commonly reported for this species (Broders and Forbes 2004, Perry and Thill 2007, Timpone et al. 2010).

Under the Endangered Species Act, there are tree harvest restrictions within 150 ft of known, occupied northern long-eared bat maternity roost trees in June and July. For more details on these restrictions, see the U.S. Fish and Wildlife Service website (https://www.fws.gov/Midwest/endangered/mammals/nleb/index.html). We intend to use the data collected in this project to inform future management decisions regarding the northern long-eared bat as WNS continues to spread across the United States.

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Appendix A. Number of Identified Roosts by Tree Species

Table of bat roost trees identified in 2017 by tree species and bat species. Some roost trees were not identifiable to species due to advanced decay. Six roosts not included below were located in buildings.

		# of Unique Roosts			
Tree Species Latin Name	**Common Name**	**EPFU**	**MYLU**	**MYSE**	**Total**
Populus tremuloides	Quaking/trembling aspen	2	5	9	16
Quercus alba	White oak	0	0	7	7
Acer saccharum	Sugar maple	0	0	6	6
Quercus rubra	Northern red oak	0	0	6	6
Unknown	Unknown	3	1	2	6
Ulmus americana	American elm	0	0	5	5
Acer rubrum	Red maple	0	1	3	4
Populus grandidentata	Big-tooth aspen	1	0	3	4
Tilia americana	Basswood	1	1	2	4
Betula papyrifera	Paper birch	0	0	3	3
Fraxinus pennsylvanica	Green ash	1	1	1	3
Populus spp.	Aspen (species unknown)	2	1	0	3
Acer negundo	Box elder	1	0	1	2
Celtis occidentalis	Hackberry	0	0	2	2
Fraxinus nigra	Black ash	0	2	0	2
Acer saccharinum	Silver Maple	0	0	1	1
Acer spp.	Maple (species unknown)	0	0	1	1
Juniperus virginiana	Eastern red cedar	1	0	0	1
Pinus resinosa	Red pine	0	0	1	1
Prunus serotina	Black cherry	0	0	1	1
Quercus ellipsoidalis	Northern pin oak	0	0	1	1
Quercus macrocarpa	Bur oak	1	0	0	1
Robinia pseudoacacia	Black locust	0	0	1	1
	Total:	13	12	56	**81**

NRRI Technical Report – 2018

Historical northern long-eared bat occurrence in Minnesota based on acoustic surveys

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Morgan Swingen, M.S.

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Summary

Although long thought to exist throughout the forested region of Minnesota, occurrence records for northern long-eared bats (*Myotis septentrionalis*) were historically based on winter hibernacula records and sporadic summer observations. The ability to record and identify bats by their echolocation calls allowed scientists to more systematically survey for bats in Minnesota beginning in the 2000s; however, these data were not compiled in a central database. With the arrival of white-nose syndrome in Minnesota and the federal listing of the northern long-eared bat in 2015 as threatened under the Endangered Species Act, the need for a more detailed and current distribution map for this species was evident. In this report, we summarize the occurrence records for northern long-eared bats based on specimens collected, existing acoustic survey data from various sources collected prior to 2015, and acoustic survey data collected from 2015 to 2017. Northern long-eared bats do appear to be distributed throughout the forested region of Minnesota. Presence has been documented in the northern half of the state, surrounding the Twin Cities metropolitan area, and in the southeast corner of the state. Detection of the northern long-eared bat in almost every attempt suggests that the species is also present in unsurveyed regions of the forested regions of the state, although it is less common than the little brown bat (*M. lucifugus*), especially after white-nose syndrome has led to mortalities in Minnesota.

Cover photograph: The cover shows an Anabat detector enclosed in a protective box with a reflector plate that would reflect bat calls into the microphone.

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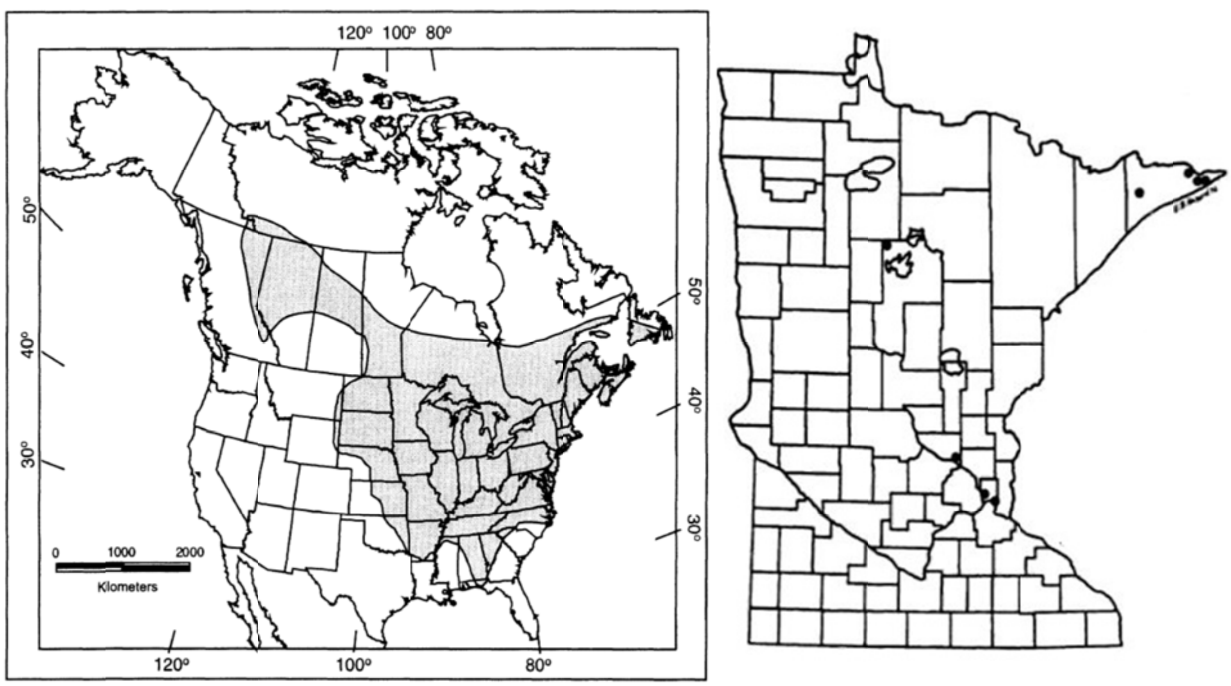
Introduction

Northern long-eared bats (*Myotis septentrionalis*) are small bats that hibernate in caves and mines in the winter. Other names for the northern long-eared bat in the historical literature include *Vespertilio gryphus* var. *septentrionalis* and *Myotis keeni septentrionalis* (Caceres and Barclay 2000). In some older literature, the northern long-eared bat is referred to as *Myotis subulatus* (Jackson 1961). The northern long-eared bat ranges throughout much of eastern North America based on the species distribution map, although specimen records in Minnesota are relatively scarce (Fig. 1).

Figure 1. Distribution of northern long-eared bat in North America (Caceres and Barclay 2000) and in Minnesota (Hazard 1982). The North American distribution map was originally published in a Mammalian Species account, and the Minnesota map was created by the Bemidji State University Biology Department and originally published as Map 13 in *The Mammals of Minnesota* (Hazard 1982).



Older references often indicate that the northern long-eared bat is relatively common in Minnesota forests in the summer, although the little brown bat (*Myotis lucifugus*) appears to be the most common *Myotis* species in Minnesota. Occurrence records of *Myotis* species come from winter hibernacula records and from occasional specimens captured in the months when bats are not in hibernacula. The little brown bat has more historical records because it often roosts in buildings during the summer, while the northern long-eared bat usually roosts in trees and therefore is less likely to be encountered by humans.

The first publications on mammals in Minnesota did not list the northern long-eared bat as present. For example, Herrick (1892) listed only the little brown bat in the *Myotis* genus. The northern long-eared bat was likely present; this is probably another instance of the little brown bat being easier to find because it roosts in buildings in the summer.

The first published indication of the northern long-eared bat in Minnesota was in a list of Minnesota mammals compiled by University of Minnesota professor C.E. Johnson in 1916, in which the range of the northern long-eared bat was described as including the “entire state” (Johnson 1916). The northern long-eared bat was described as very common throughout Itasca County in north central Minnesota in 1919 (Cahn 1921), although Cahn called it *M. subulatus* in that publication. Cahn also listed the little brown bat as present but did not say that it was either common or very common.

In a second compilation of the Mammals of Minnesota, the little brown bat was considered the most common *Myotis* bat in the summer, although hibernacula locations appeared to be unknown because winter locations were not discussed (Surber 1932). The northern long-eared bat was described as having only a local distribution in Minnesota, although it could be found throughout the state. One known specimen from Elk River in Sherburne county was referenced.

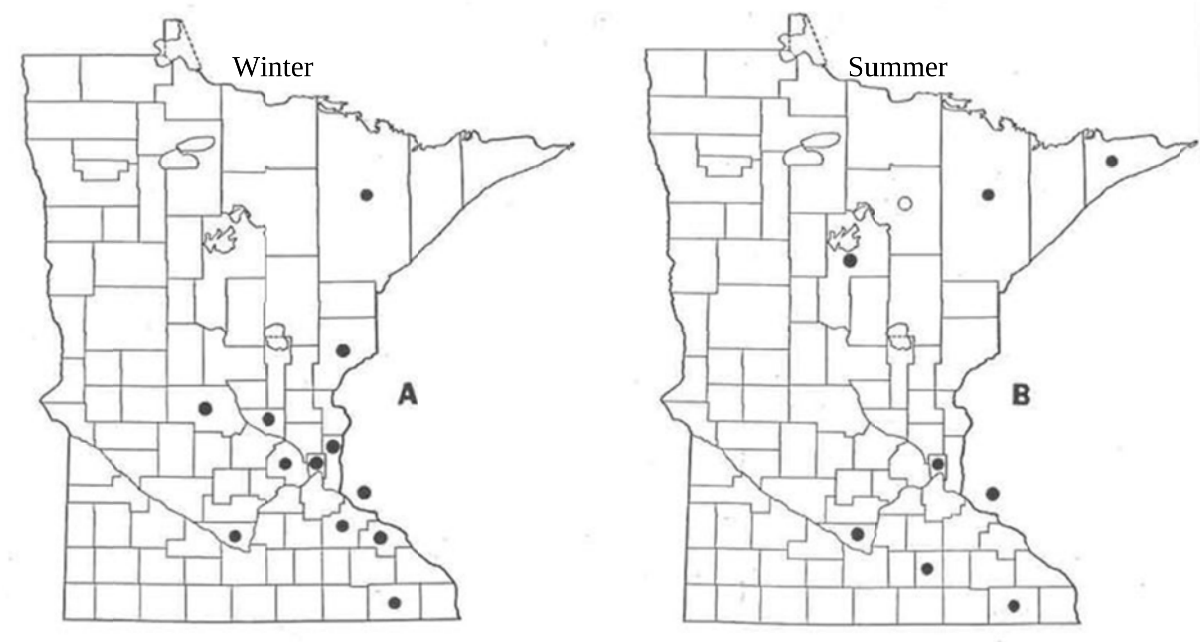
There are few published records of the northern long-eared bat from the mid 1900s. A few northern long-eared bats were found hibernating in caves during winter surveys in 1940–1941 in Nicollet, Goodhue, Fillmore, and Wabasha counties (Rysgaard 1942). Rysgaard indicates the northern long-eared bat is thought to be relatively common throughout Minnesota, although he also says that it is rarely found in hibernacula compared to other bat species. Other counties with documented presence of the northern long-eared bat included Clearwater, Itasca, St. Louis, Lake, Pine, Sherburne, and Stearns counties. Northern long-eared bats were found hibernating in sewers in St. Cloud, MN in 1952 (Goehring 1954).

In a third compilation of the mammals of Minnesota by Gunderson and Beer in 1953, the theme of the little brown bat being more common than the northern long-eared bat continues. The little brown bat was documented present in 19 counties in Minnesota, while the northern long-eared bat was listed as present in 7 counties in Gunderson and Beer’s Mammals of Minnesota. The authors again indicate that the northern long-eared bat is more common than specimen records indicate, although also saying that in hibernacula the little brown bat is much more common.

In 1982, Bemidji State University biology professor Evan B. Hazard published another compilation of the mammals of Minnesota, with maps based on specimen records at the township level (Fig. 1). Counties with northern long-eared bat presence in Fig. 1 include Cass, Cook, Sherburne, and Ramsey. Several of the counties listed in earlier references (e.g., Rysgaard 1942, Goehring 1954) are not included because specimens were not associated with those observations. As in Gunderson and Beer (1953), the little brown bat was listed as present in many more counties than the northern long-eared bat in Hazard’s book (30 counties for the little brown bat compared to 4 counties for the northern long-eared bat).

A literature review and additional surveys for Minnesota bat species were conducted by Gerda Nordquist and Elmer Birney in the early 1980s, leading to updated distribution maps which included known museum specimens, literature records, and observations from summer and winter field surveys (Fig. 2). In their literature review the little brown bat was documented in 55 counties, compared to 15 counties for the northern long-eared bat. Several hibernacula were identified, including the largest known hibernating populations of the little brown bat and the northern long-eared bat in Minnesota, at the Soudan Underground Mine in St. Louis County (Nordquist and Birney 1985).

Figure 2. Maps of known northern long-eared bat winter (left) and summer (right) distribution records in Minnesota as of 1985. Circles appear in counties for which records of northern long-eared bats occur, and do not indicate exact locations. Maps in Figure 2 were originally published as Figure 3 in the report "Distribution and Status of Bats in Minnesota" (Nordquist and Birney 1985).



Most of the earlier records of bat presence in Minnesota are from hibernacula, captures of bats in summer roosts, or specimens obtained incidentally. It became easier to document presence of bat species during the summer when the technology to record and identify the ultrasonic calls of bats became available to field biologists in the early 1980s (Fenton and Bell 1981). Acoustic surveys for bats were first conducted by the Minnesota Department of Natural Resources (MN DNR) in Minnesota in the early 2000s. Additional survey work has been conducted by state and federal agencies, universities, and private consulting companies. Some of these projects were published in peer-reviewed literature or as theses; others are only present in gray literature or are unavailable.

Ultrasonic recording technology has advanced greatly in the last decade, but even now not every call that is recorded can be identified to species. Early acoustic detectors recorded data in zero-crossing (ZC) format, a format which stored a limited amount of acoustic information compactly due to data storage limitations. More recently, acoustic detectors that record data in full-spectrum (FS) formats were developed. The FS format stores a greater amount of information about each call, which can make it easier to identify bat species.

The echolocation calls of bat species vary depending on their body size and foraging strategy. Minnesota's seven bat species make either low-frequency calls (hoary bat (*Lasiurus cinereus*), big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*)) or high-frequency calls (northern long-eared bat, little brown bat, tricolored bat (*Pipistrellus subflavus*), eastern red bat (*Lasiurus borealis*)). Low-frequency calls and high-frequency calls are easily differentiated, but it can be difficult to assign calls to a species within either the low-frequency or the high-frequency group. As might be expected, the calls of some bats within the same genus, such as the northern long-eared bat and the little brown bat, can be difficult to assign to a species. Northern long-eared bats and little brown bats are particularly difficult to distinguish due to the overlapping range of many call characteristics. In addition, for high frequency bats, some little brown bat and eastern red bat calls have similar characteristics. For low-frequency bats, big brown bat and silver-haired bat calls are very similar. Examples of the calls made by different species and additional discussion of identification of bat calls to species are in Swingen et al. (2018a).

Since 2006, cave-hibernating bat populations in the United States have declined sharply from white-nose syndrome (WNS). First documented in New York state, WNS has spread westward to 32 U.S. states and 7 Canadian provinces, killing millions of bats (U.S. Fish and Wildlife Service 2012). The northern long-eared bat is particularly susceptible to WNS, with declines of 90–100% in many eastern U.S. hibernacula (Turner et al. 2011). WNS was first confirmed in Minnesota in 2016, and subsequent winter surveys have confirmed decreasing numbers of bats (MN DNR 2016, 2017). When the northern long-eared bat was listed as Threatened under the Endangered Species Act in 2015, it became necessary to increase understanding of the distribution of this species in Minnesota. We used historic locations reviewed above, records downloaded from the Global Biodiversity Information Facility, the Minnesota Biodiversity Atlas, and available acoustic data to create an updated map of northern long-eared bat detections.

Methods

We compiled bat acoustic data collected in Minnesota by various entities prior to 2015. We attempted to identify all potential sources of bat acoustic data, including state agencies, federal agencies, universities, private consulting firms, and industry partners. If the original data was available, it was obtained in addition to a summary of the dataset and/or file identifications.

If the files were identified to species by the original source or author, we used the results of the original analysis. If the files were not identified by the original source or author, and the original recording data was available to us, we analyzed the files using the software program Kaleidoscope Pro (version 4.0.4). Data were processed in Kaleidoscope using the “Moderate” setting, with the “Minnesota” set of candidate species:

Big brown bat	*Eptesicus fuscus* (EPFU)
Eastern red bat	*Lasiurus borealis* (LABO)
Hoary bat	*Lasiurus cinereus* (LACI)
Silver-haired bat	*Lasionycteris noctivagans* (LANO)
Little brown bat	*Myotis lucifugus* (MYLU)
Northern long-eared bat	*Myotis septentrionalis* (MYSE)
Tricolored bat	*Perimyotis subflavus* (PESU)

We did not analyze any of the acoustic data using the Sonobat software program, because most of the existing data was from zero-crossing detectors, which cannot be analyzed by Sonobat.

There are some legal filings for wind turbine projects that can be found with an internet search. The acoustic data has been collected for these projects, but the data presentation in earlier projects is limited to high-frequency and low-frequency bat groups. Because the calls are not differentiated to species, the high-frequency bat calls could be from the northern long-eared bat, the little brown bat, or the eastern red bat. An example of this type of analysis is Derby and Dahl (2008).

Other legal filings that were done after the northern long-eared bat was listed as threatened under the ESA could be used. One example of this type of project is the Palmers Creek project in Yellow Medicine County (MDOC 2018), in which northern long-eared bats were not found.

Results

We compiled acoustic data and results from 2003–2014 from 10 sources (Table 1). Data were from 208 passive surveys, 47 active surveys, and 13 driving transects located in 21 Minnesota counties. Sources included the Minnesota Biological Survey, U.S. Forest Service, University of Minnesota, and WEST Inc. environmental consulting company. Acoustic records that are not publicly available, such as an acoustic study for the proposed new route for the Line 3 pipeline project by Enbridge, Inc. (https://www.enbridge.com/Line3ReplacementProgram.aspx), are not included in Table 1.

Table 1. Sources of bat acoustic data collected in Minnesota compiled for this analysis. For data type, ZC = zero-crossing and FS = full-spectrum.

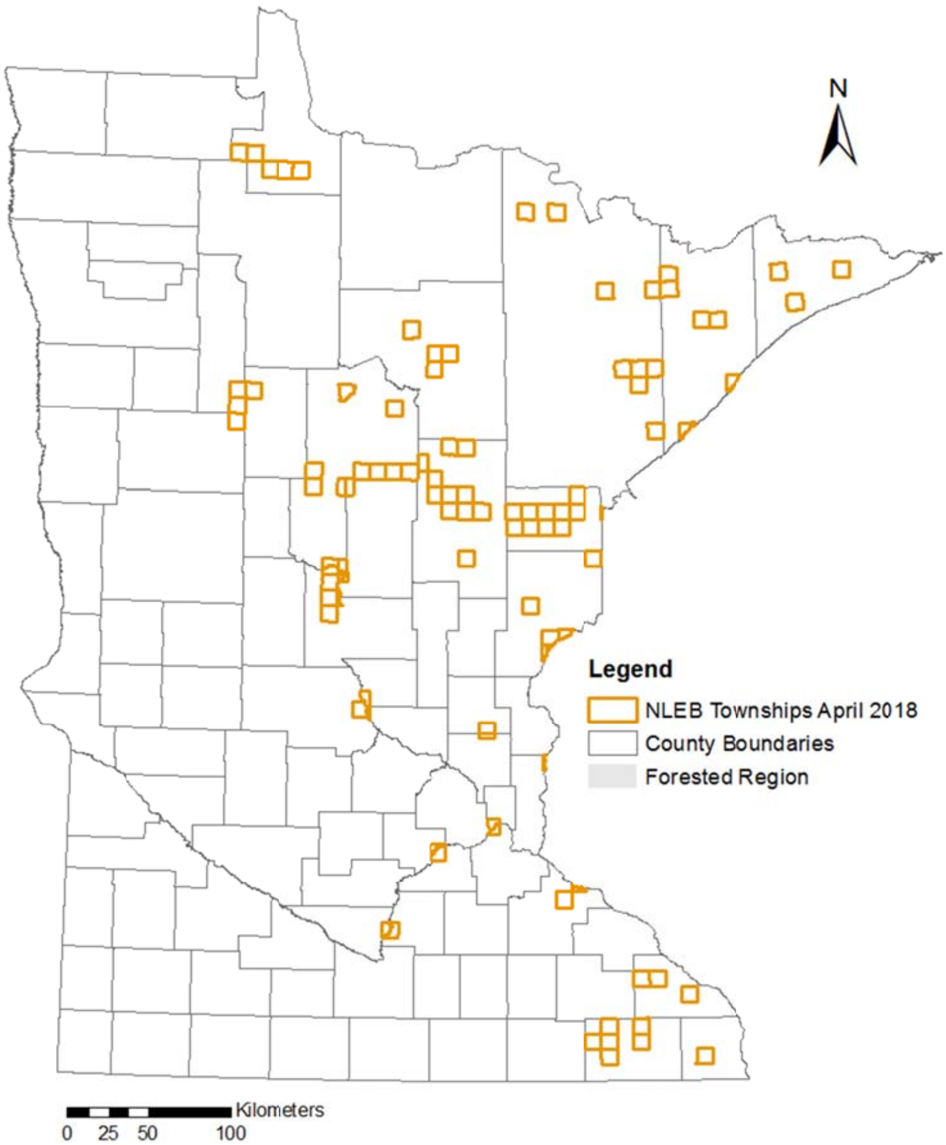
Source	Years Data Collected	# Locations Data Collected	# Files Recorded	Type of Data	Files Identified by Source?
UMD – NRRI	2009–2014	106	52,790	ZC	Yes/No
Superior National Forest	2009–2014	7[1]	4,554	ZC	Yes (WEST)
Chippewa National Forest	2011–2014	5[1]	3,283	FS	Yes (WEST)
MN DNR – Biological Survey	2003–2014	Unknown[2]	Unknown[2]	ZC	Yes
MN DNR/ MN DOT	2014	16	25,547	ZC	Yes
National Park Service	2003	3	1,488	ZC	Yes
UPM Blandin	2014	3	790	ZC	Yes
Camp Ripley Training Center	2006–2014	11[3]	4,834	ZC	No
Dixon (2012)		47		ZC	Yes[4]
Carlton County[5]	2016	2	1,450	FS	Yes
Total		**259**			

[1] These locations are all driving transects.
[2] MBS data include confirmed MYSE calls. Call file data is not available.
[3] One of these 11 locations is a driving transect.
[4] Did not differentiate between MYSE and MYLU.
[5] Sichmeller and Hammond 2017.

There were 16 records for *Myotis septentrionalis* and *Myotis keenii* in the Global Biodiversity Information Facility (GBIF) and the Minnesota Biodiversity Atlas databases (GBIF.org 2018a, b). The GBIF database search for *Myotis septentrionalis* and *Myotis keenii* returned one record from Elk River and one record from St. Cloud (GBIF_1, GBIF_2). The Minnesota Biodiversity Atlas (MBA) of the Bell Museum of Natural History has 14 specimens from Minnesota that were collected from 1934 to 1983 (MBA 2018). Hazard, Gunderson and Beer, and Nordquist probably looked at some of these specimens from the Bell Museum to make their maps! Because the northern long-eared bat is listed as a threatened species, the location is only reported at the county level in the MBA. Counties included Cook, Goodhue, Hennepin, Nicollet, Ramsey, St. Louis, and Stearns, all of which had been reported in the earlier literature.

As a result of the northern long-eared bat being listed under the ESA, the MN DNR maintains records of locations of known roost trees. These records are currently located in 28 counties spread throughout the forested area of Minnesota. For all of these analyses of northern long-eared bat presence, an important consideration of this map is that absence of a record does not mean that northern long-eared bats are not present.

Figure 3. Records of northern long-eared bat roost trees by township stored in the database maintained by the MN DNR. Records are current as of April 2018.



Our review of the publications, museum records, and recent acoustic datasets resulted in documentation of northern long-eared bat presence in 38 of the 88 Minnesota Counties (Table 2). The main outcome of the synthesis of current knowledge of northern long-eared bat presence was to fill in some of the vacant spots present in earlier reviews.

Table 2. Counties in Minnesota with documented presence of northern long-eared bat. Column labels refer to publication date for Cahn (1921), Surber (1932), Rysgaard (1942), Goehring (1954), Gunderson and Beer (1953), Hazard (1982), Nordquist and Birney (1985). The column labelled "MNDNR" refers to known locations of northern long-eared bat roosts (Fig. 3), and the column labelled "T-1" refers to the sources compiled in Table 1. The column labelled "All" includes all counties in this table with northern long-eared bat presence documented.

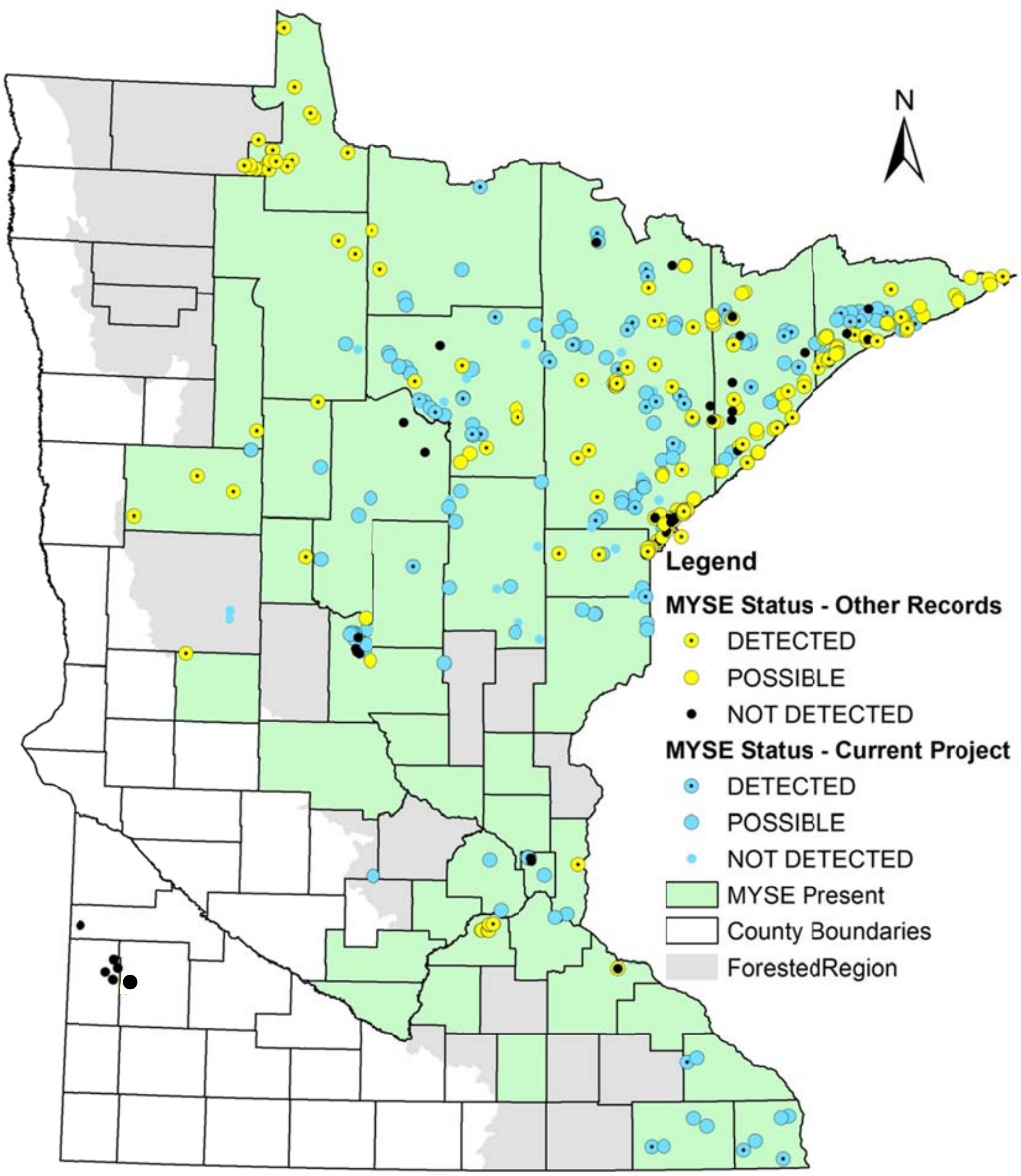
County	1921	1932	1942	1954	1953	1982	1985	MNDNR	T-1	All
Aitkin								1		1
Anoka								1		1
Becker								1	1	1
Beltrami									1	1
Benton								1		1
Big Stone										
Blue Earth										
Brown										
Carlton								1	1	1
Carver								1		1
Cass						1	1	1		1
Chippewa										
Chisago										
Clay										
Clearwater				1				1	1	1
Cook						1	1	1	1	1
Cottonwood										
Crow Wing								1		1
Dakota								1		1
Dodge										
Douglas									1	1
Faribault										
Fillmore			1				1	1		1
Freeborn										
Goodhue			1		1		1	1		1
Grant										
Hennepin							1			1
Houston								1		1
Hubbard								1	1	1
Isanti								1		1
Itasca	1			1			1	1	1	1
Jackson										
Kanabec										
Kandiyohi										
Kittson										
Koochiching									1	1
Lac qui Parle										
Lake				1				1	1	1
Lake of the Woods								1	1	1

Table 2, Continued.

County	1921	1932	1942	1954	1953	1982	1985	MNDNR	Fig. 3	All
Le Sueur								1		1
Lincoln										
Lyon										
Mahnomen										
Marshall										
Martin										
McLeod										
Meeker										
Mille Lacs										
Morrison								1		1
Mower										
Murray										
Nicollet			1		1		1			1
Nobles										
Norman										
Olmsted										
Otter Tail										
Pennington										
Pine				1	1		1	1		1
Pipestone										
Polk										
Pope										
Ramsey					1	1	1	1		1
Red Lake										
Redwood										
Renville										
Rice										
Rock										
Roseau										
Saint Louis				1	1		1	1	1	1
Scott								1	1	1
Sherburne		1		1	1	1				1
Sibley							1			1
Stearns				1	1			1		1
Steele							1			1
Stevens										
Swift										
Todd										
Traverse										
Wabasha			1		1		1			1
Wadena									1	1
Waseca										
Washington							1	1	1	1
Watonwan										
Wilkin										
Winona					1			1		1
Wright										
Yellow Medicine										

Combining pre-2015 acoustic survey data with other known locations shows that northern long-eared bats are distributed throughout the forested region of Minnesota (Fig. 4). Acoustic surveys and occurrence records have been focused on the northern half of Minnesota, around the Twin Cities metropolitan area, and in the southeastern corner of the state. However, based on the documented distribution of northern long-eared bats from recent research projects, it is likely that the species is present throughout the forested portion of the state, consistent with Johnson (1918), Surber (1932), Gunderson and Beer (1953), Hazard (1982), and Nordquist and Birney (1985).

Figure 4. Map of pre-2015 bat acoustic survey locations in Minnesota showing detection of northern long-eared bat (MYSE) calls. Sites marked with yellow are from past records, and sites marked with blue are from the current project (Swingen et al. 2018a). Counties with records are shaded green.



Discussion

Historically, northern long-eared bats were thought to be distributed across Minnesota, although this was originally based on relatively few documented specimen locations. Hibernacula sites were unknown in the early 1900s, and northern long-eared bats are less likely to be found because of the tendency of northern long-eared bats to roost in trees instead of buildings. Most references to abundance after the 1940s indicate that the little brown bat is the most common bat in Minnesota and that the northern long-eared bat is less common. Many of the references also indicate that the northern long-eared bat is more common than occurrence records indicate.

The several books that have been published on the Mammals of Minnesota generally indicate a summer range throughout the state, although there were few documented locations to support this (e.g., 8 specimens in Hazard (1982), 9 locations in Gunderson and Beer (1953)). Even as late as 1985, there were only 8 counties in Minnesota with documented locations of the northern long-eared bat in summer (Fig. 2, from Nordquist and Birney 1985). Thus, although specimens had been identified in counties distributed from north to south in Minnesota, the validity of the extent of summer range could have been challenged.

Acoustic detectors made it possible to more efficiently find northern long-eared bats in the summer, and the analysis of acoustic data has provided strong support for northern long-eared bats being distributed throughout at least the forested part of Minnesota. There were few deployments of acoustic detectors in the southern half of Minnesota prior to 2015 (Fig. 4), but deployments and mist-net captures from 2015 to 2018 provided additional support for presence of northern long-eared bats in the southern half of Minnesota (Swingen et al. 2018a, b).

One important aspect of acoustic data is that it provides evidence of distribution, but it is still not possible to use acoustic data to determine abundance of different species. As discussed in the Introduction (p. 6), while it is easy to differentiate high-frequency and low-frequency species from the bat calls, it can be difficult to differentiate species within each frequency group. Because of similarities of calls among species, relative abundance calculations must also be qualified with the identification criteria used. Human interpreters and software programs do not always agree when assigning species identifications to a call file (Lemen et al. 2015).

Although recording equipment and analysis software have made bat surveys more practical, acoustic file identifications are still less reliable than confirming species presence through mist-netting. The northern long-eared bat in particular is difficult to confirm positively from acoustic records because its calls are so similar to calls made by the closely related little brown bat. The automated programs appear to be more likely to identify a call to be from a little brown bat, because not every call made by a northern long-eared bat has the distinctive high-frequency part of the call present.

Another important aspect of both acoustic surveys and mist-netting is that it is difficult to impossible to prove absence. The only area of the state where northern long-eared bats have not been found during any survey is in the southwestern counties, where forested areas cover a small portion of the landscape. In all other areas that have been surveyed, at least some surveys have indicated presence of northern long-eared bats. It is probably a safe assumption that in the forested portion of Minnesota, even if one acoustic survey fails to detect northern long-eared bats, another acoustic survey in the area would detect their presence.

Overall, based on documented locations and acoustic surveys, the northern long-eared bat is present throughout the forested region of Minnesota. The mist-netting and acoustic detection parts of this project, conducted from 2015 to 2017, provided additional data on the distribution of the northern long-eared bat in Minnesota (Swingen et al. 2018a, b).

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