Sound bite of Project Outcomes and Results

The primary goal of this project was to map aquatic moose habitat moose in northern Minnesota, which was accomplished with a habitat suitability approach. The secondary goal of this project was to assess the relationship of moose foraging to aquatic plant and fish diversity. This goal was not achieved as intended due to field work limitations that occurred as a result of the COVID-19 global pandemic. The tertiary goal of this project was to develop broader impact materials about moose ecology and conservation. While a draft storyboard of an educational video was developed, video footage was not captured due to field work restrictions resulting from the COVID-19 global pandemic and the inherent challenge of filming wild moose. Broader impacts were partially achieved through presentations and support of the Minnesota Zoo's efforts to redesign their moose exhibit. The overall outcome and result of this work is a better understanding of aquatic moose habitat in Minnesota; secondary outcomes include support of Minnesota Zoo and partial support of scientific papers. Project funds were not completely spent.

5/14/25 LCCMR Staff note: ENRTF funds were not used for the scientific papers mentioned above, which were published before the July 1, 2019 start of this award.

Overall Project Outcome and Results

Overall, this project was only partially completed due to the challenges of the COVID-19 pandemic, personnel turnover, the challenges inherent in trying to film wild animals, and restrictions on field work as a result of pandemic safety concerns. After discussion and with guidance from LCCMR staff (i.e., Megan Lennon, Project Manager) we addressed these challenges to the best of our ability. This led to a focus on developing the habitat suitability index model approach that used pre-existing datasets since we did not have permissions to conduct field work within the project timeframe. As a consequence, not all project funds were used; funds were returned to LCCMR.

This project did result in the presentation and dissemination of key information about moose ecology and conservation. Specifically, moose are a culturally and economically important species to Minnesotans; they are among the state's most iconic wildlife species and are valued for multiple reasons. Moose are well known for how they use aquatic habitats such as small lakes, ponds, and wetlands. This project emphasized the less well known natural history that aquatic plants provide protein and salt-rich plants to moose. Messaging included that in Minnesota little is known about what sort of aquatic habitats moose use in Minnesota at the landscape scale.

Despite the challenges of the COVID-19 global pandemic, this project modeled and produced a map of the key aquatic habitats that are important moose using existing data layers and a novel habitat suitability approach. Minnesotans benefit from this project because it developed methods to identify important habitat, supported

efforts of the Minnesota Zoo, produced a current, and maybe first, map of moose habitat suitability in northeastern Minnesota, and disseminated less known moose natural history. The mapping results can be used by natural resource professionals to better understand moose habitat and conserve moose populations statewide.

Project Results Use and Dissemination
Project results have been shared with natural resource professionals via slide presentations. We attended a multi-day 'Moose Exhibit & Interpretation' meeting at the Minnesota Zoo to share results with the moose experts to support efforts to update the zoo's moose exhibit. We presented information on moose aquatic ecology to the National Park Service, Voyageurs Conservancy, and attendees of the Minnesota chapter of The Wildlife Society meetings. Presentation content for educational outreach and wildlife management has been created. These are broader impact and research tools, respectively. This project also helped to indirectly support two peer-reviewed, open-access scientific publications. No project funds were spent on publishing fees. While these publications did not incorporate new data collected as part of this project the work to complete these publications did directly benefit and was supported by efforts of this project. In other words, these papers began before this project and formed some of the basis for developing this project.

5/14/25 LCCMR Staff note: ENRTF funds were not used for the scientific papers mentioned above, which were published before the July 1, 2019 start of this award. ENRTF funds were not used for the above presentations that occurred before the July 1, 2019 start of this award.

Today's Date: April 14, 2025

Final report

Date of Work Plan Approval: June 5, 2019

Project Completion Date: 4 years, June 30, 2023

PROJECT TITLE: Mapping Aquatic Habitats for Moose

Project Manager: Dr. Joseph K. Bump

Organization: University of Minnesota

College/Department/Division: Department of Fisheries, Wildlife, and Conservation Biology

Mailing Address: FWCB 135 Skok Hall, Upper Buford Circle

City/State/Zip Code: St. Paul, MN

Telephone Number: 612 624-2255

Email Address: bump@umn.edu

Web Address: https://fwcb.cfans.umn.edu/personnel/joseph-bump

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Location: Northeast
Counties: Cook, Itasca, Koochiching, Lake, Lake of the Woods, St. Louis

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Total Project Budget: $199,000
Amount Spent: $133,388
Balance: $65,612

Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 03l as extended by M.L. 2022, Chp. 94, Sec. 2, Subd. 19 (c.1) [to June 30, 2023]

Appropriation Language: $199,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to determine key water habitats used by moose in northern forested regions of Minnesota, measure the effects of moose foraging on aquatic plant and fish diversity, and provide educational programming materials for the public.

M.L. 2022 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2023]

I.   PROJECT STATEMENT:

Moose use aquatic habitats for multiple reasons (e.g. to consume salt-rich plants), but almost nothing is known about what sort of aquatic habitats moose prefer and how moose can potentially create positive feedbacks in near-shore habitats critical to not only moose but also other lake plants and animals.

Goal: We'll identify key aquatic habitats for moose and measure how moose affect aquatic habitats in shallow ponds and lakes to assess the potential for positive feedbacks in habitat quality.

Why? Aquatic habitats are critical moose habitat. By feeding in aquatic habitats moose may significantly affect a variety of abiotic (e.g., temperature, nutrients) and biotic (e.g., periphyton, macrophytes, invertebrates, fish) functions in small lake, stream, and pond ecosystems. Small water bodies are also critical for moose nutrition, thermoregulation, and survival. By determining aquatic habitat selection and key effects of moose on aquatic habitats, we can then assess feedbacks to the moose populations and other species that depend on small lakes and ponds.

Our specific, direct outcomes are to:
1.   Determine key water bodies used by moose in the Northern Forest region of Minnesota;
2.   Measure key effects of moose on aquatic habitat productivity and community structure; and
3.   Provide educational programming material for outreach to the general public.

We will achieve these goals and outcomes by:
1.   Mapping high-to-low moose use in water bodies with existing data from GPS collared moose;
2.   Using existing data and new measurements to assess moose effects on aquatic plants and fish; and
3.   Create a short documentary film on the importance of aquatic habitats to moose and how, in turn, moose can affect aquatic habitats, which may create key positive feedbacks that favor moose population health and other aquatic life.

II.   OVERALL PROJECT STATUS UPDATES:

First Update March 1, 2020
A project manager was identified for hiring, but that individual chose a different permanent position on short notice. This has meant that the PI has worked to meet project goals individually. This resulted in a slow start, but progress towards goals and outcomes was still made by the PI during this reporting period and at no cost to the project. Recruiting a graduate student with the necessary qualifications is ongoing. Outcomes for Activity #1 and #3 are partially complete.

The COVID-19 pandemic, Minnesota's stay-at-home order, and consequent University of Minnesota restrictions on research activities has challenged our progress this spring and will likely affect our field work throughout the summer. This will most likely affect the timing of outcomes of Activity #2, but permissions and future plans are too uncertain at this time so say for sure. Still, we plan to make progress in other areas of the project, e.g. work to create short documentary film on moose and finalize an aquatic habitats map.

While not an expectation or activity of this project, the PI was invited to participate in developing complementary funding for a comparison of moose use of aquatic habitats between the Minnesota and Isle Royale, National Park populations. This an excellent opportunity to enhance this project's impact and value.

Second Update September 1, 2020
As expected, the COVID-19 pandemic, Minnesota's stay-at-home order, and consequent University of Minnesota restrictions on research activities challenged our progress this past summer and slowed hiring. Field work was not

possible due to COVID-19 related travel restrictions and safety concerns. Expenditures are low, given late hiring. In the future I expect to request a no-cost extension to complete this project, if permitted as has occurred recently for other ENRTF supported projects.

A full time postdoctoral scholar and student will begin on this project starting spring semester, January 2021.

We have established a collaboration with [Benjamin Olson](#), a professional, Minnesota based photographer to help generate content, both photo and video, for Activity #3.

Third Update March 1, 2021
The COVID-19 pandemic, Minnesota's stay-at-home order, and consequent University of Minnesota restrictions on continued to challenge our progress during the academic year. Depending on what occurs this summer, an amendment request may be likely in September. Hiring of a postdoctoral research scientist and student for the summer has occurred, with spending just beginning after May 2021, hence expenditures are still low.

Despite the COVID-19 challenges, we were able to hold virtual meetings with two other biologists with moose expertise (Drs. William Severud and John Berini). A result of this effort was a conceptual plan to develop a habitat suitability index model for moose, which should be possible despite the COVID-19 challenges and it will also help address the activities and outcomes.

Fourth Update September 1, 2021
Summer 2021 field work was again challenged by COVID-19 restrictions. We were not permitted to sample lakes. Still, progress was made on this project albeit slower than expected. We are currently working with remote sensing specialist and the University of Minnesota's Geographic Information Science program to assess moose habitat and meet and enhance outcomes for Activities 1 and 2. We are now working with both graphic and video artists to meet Activity 3 outcomes. Capturing suitable footage of moose has proven to be a challenge, which is not surprising. I still expect to be able to meet the project outcomes, but have requested more time to do so (pending).

Fifth Update March 1, 2022
In collaboration with the University of Minnesota's Geographic Information Science Program significant progress was made towards completing Activities 1 and 2. A MGIS graduate student used Object Based Image Analysis (OBIA) through Trimble eCognition (Version 9.4.0) to determine the abundance and distribution of areas of moose habitat in 1-m aerial imagery. We continue to work with both graphic and video artists to meet Activity 3 outcomes. Capturing suitable footage of moose in aquatic habitats still proves to be a challenge, which is not surprising. I still expect to be able to meet the project outcomes, appreciate the 1-year no cost extension, and am considering an amendment for the next update/reporting period.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

August 29, 2022 LCCMR made updates to the project materials to ensure that the correct allocation amount ($199,000) was consistently expressed.

Sixth Update as of September 1, 2022:
The extraneous $600 that was incorrectly included in the last update was removed from the Other section of the budget, specifically from publishing.
While the pace of this project has been challenged by personnel turnover, COVID restrictions, and the difficulty of filming moose in the wild, recent discussion and advising with LCCMR staff have helped plot a path forward to meet of the project objectives. Activity 1 will definitely be completed as planned.

Seventh Update as of March 1, 2023:

We are on track to complete this project and submit a final report before August 15, 2023.

Final Report as of June 30, 2023 (to be submitted before August 15, 2023); May 23, 2024:
Moose are a culturally and economically important species to Minnesotans. They are among the state's most iconic wildlife species and are valued for multiple reasons. Moose are well known for how they use aquatic habitats such as small lakes, ponds, and wetlands. Aquatic plants provide protein and salt-rich plants to moose, but in Minnesota little is known about what sort of aquatic habitats moose use at the landscape scale. This project mapped key aquatic habitats that are important moose habitat. Minnesotans benefit from this project because it developed methods to identify important habitat, collaborated with leaders in moose conservation and management to create educational materials, and produced the first map of moose habitat suitability in northeastern Minnesota. Results from this project were used to assist the Minnesota Zoo in the design and development of their updated moose exhibit. The mapping results can be used by state, tribal, and federal natural resource agencies to better manage moose habitat and conserve moose populations statewide.

REVISED Final Report as of April 14, 2025:
Overall, this project was only partially completed due to the challenges of the COVID-19 pandemic, personnel turnover, the challenges inherent in trying to film wild animals, and restrictions on field work as a result of pandemic safety concerns. After discussion and with guidance from LCCMR staff (i.e., Megan Lennon, Project Manager) we addressed these challenges to the best of our ability. This led to a focus on developing the habitat suitability index model approach that used pre-existing datasets since we did not have permissions to conduct field work within the project timeframe. As a consequence, not all project funds were used; funds were returned to LCCMR.

This project did result in the presentation and dissemination of key information about moose ecology and conservation. Specifically, moose are a culturally and economically important species to Minnesotans; they are among the state's most iconic wildlife species and are valued for multiple reasons. Moose are well known for how they use aquatic habitats such as small lakes, ponds, and wetlands. This project emphasized the less well known natural history that aquatic plants provide protein and salt-rich plants to moose. Messaging included that in Minnesota little is known about what sort of aquatic habitats moose use in Minnesota at the landscape scale.

Despite the challenges of the COVID-19 global pandemic, this project modeled and produced a map of the key aquatic habitats that are important moose using existing data layers and a novel habitat suitability approach. Minnesotans benefit from this project because it developed methods to identify important habitat, supported efforts of the Minnesota Zoo, produced a current, and maybe first, map of moose habitat suitability in northeastern Minnesota, and disseminated less known moose natural history. The mapping results can be used by natural resource professionals to better understand moose habitat and conserve moose populations statewide.

Amendment Request 4/14/25

The project manager is removing $16,847.43 in unallowed personnel costs from the project. This results in the amount spent being reduced from $150,235 to $133,388 and the total balance from the project increasing from $48,765 to $65,612. Since this expense had already been paid, $16,847.43 will be reimbursed by the UMN to the ENRTF.

Amendment approved by LCCMR 5/16/25

III.   PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Determine and map key water bodies that are used by moose in northeastern Minnesota.
Description: We will collaborate with multiple agencies and tribes to synthesize and analyze moose location data to determine and map water bodies that are heavily used by moose, moderately used, and used infrequently. The

aim is to determine the key water bodies used by collared moose in NE MN so we can focus on those lakes to study at a finer scale. This effort will require synthesizing multiple data sources to determine which lakes moose use on a spectrum from high-low use, we will work within areas of known low- to-high moose density and previous research on populations in Northeastern, MN and the Greater Voyageurs Ecosystem. We will also meet with regional biologists to help determine and map high-to-low moose across water bodies in northeastern Minnesota. These methods will allow us to determine key water bodies used by moose in Minnesota.

ACTIVITY 1 ENRTF BUDGET: $50,200

Outcome	Completion Date
1. Preliminary analysis of existing data to determine and map high-to-low moose use across water bodies.	*Feb. 1st 2020*
2. Meet with regional biologists to develop a field sampling plan use across water bodies.	*May 1st 2020*

First Update March 1, 2020
Outcome #1: This outcome is nearly completed. The PI has collated existing information on moose densities across Minnesota and is in the final stages of synthesizing what is known regarding moose use of aquatic resources. Use of aquatic habitat is generally determined by availability and more likely warmer portions of the moose range.

Outcome #2: This activity is nearly complete as well. The PI met with regional biologist on multiple occasions to determine pre-existing data and field sampling. In August 2019, we attended a multi-day 'Moose Exhibit & Interpretation' meeting at the Minnesota Zoo. This was an opportunity to meet with the top moose experts in the state (G. DelGuidice, J. Forester, R. Moen, T. Wolf, M. Carstensen, S. Moore, S. Windels) to hear research summaries and discuss this project's goals. The PI met with the National Park Service research biologist Dr. Steve Windels in December 2019 to discuss data and field sampling . At no cost to the project, the PI attended the annual meeting of the Minnesota chapter of The Wildlife Society on February 18-20, 2020 in Willmar, MN. This meeting was an excellent opportunity to meet with state (MN DNR) and federal (USFWS, USGS) biologists to assess how moose use aquatic habitats in the state and develop a field sampling plan. In January 2020, the PI was invited to attend the National Park Service special meeting on '*Ecological Monitoring Framework – Monitoring the Impacts of Wolf Introduction Isle Royale National Park*.' At this meeting, moose were a major discussion point and numerous regional biologist were present with which to discuss Activity 1 outcomes. In April 2020, PI was invited to collaborate on a grant proposal focused on '*Differential habitat use by moose in contrasting landscapes: How important are aquatics?,*' which will help inform this projects goals and accomplishments.

Second Update September 1, 2020
Outcome #1: The PI has begun working with two Minnesota based moose experts, Dr. William Severud and Dr. John Berini, to finalize a moose habitat map.
Outcome #2: This outcome is complete. However, project consultation is ongoing with individuals mentioned for this outcome in the previous update.

Third Update March 1, 2021
Outcome #1: This outcome is essentially ongoing, as the PI continues to work with two Minnesota based moose experts, Dr. William Severud and Dr. John Berini, to finalize a moose habitat map.
Outcome #2: No change from previous reporting.

Fourth Update September 1, 2021
Outcome #1: Ongoing. No change from previous reporting.
Outcome #2: Complete. No change from previous reporting.

Fifth Update March 1, 2022

Outcome #1: Ongoing. No change from previous reporting.

Outcome #2: Complete. No change from previous reporting.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Please update Activity 1 and indicate what progress has been made in developing the map of moose-use in waterbodies. Have you continued to work with moose experts to identify study areas, or have study areas been identified? If so, where are they?

Beaver created ponds are often a preferred aquatic habitat for moose. Hence, we have made progress mapping aquatic habitats engineered by beavers, which is a significant step towards developing a map of aquatic habitat for moose. As manual delineation is time-intensive, and as the nature and location of beaver dams across a landscape changes quickly over time, recent studies have explored the viability of using automated remote sensing methods to identify beaver dams from satellite imagery. We have explored remote sensing methods to identify beaver impoundments that serve as moose habitat. These methods have been tested in the Kadunce River watershed in Cook County, northeastern Minnesota. Using the shapefile of delineated-by-hand beaver impoundment locations as control data, we conducted an accuracy assessment between the control data and a shapefile of beaver impoundment locations we generated using an automated remote sensing script that identifies impoundments. Results indicate that this remote sensing (eCognition) process could be used as a means for identifying beaver impoundments from satellite imagery and can be used to index and map aquatic habitat for moose. We can apply this method to other areas, overlay it with moose density estimates, and create a map that indicates aquatic habitat for moose, i.e. a aquatic habitat suitability model.

Yes, I continue to work with Dr. John Berini to understand moose distribution as it relates to aquatic habitat. Dr. Berini is a moose expert; his dissertation was completed in Minnesota in 2019, title, "Evaluating how spatial heterogeneity in forage chemistry and abundance influences diet and demographics in a declining moose (Alces alces) population in northeast Minnesota."

Potential study areas identified include 1) ponds in the Greater Voyageurs Ecosystem (Saint Louis County), e.g. Ash Lake, Long Lake, Elephant Lake, all of which are low moose density and 2) lakes accessible from the University of Minnesota Hubacheck Research Center (Lake County), e.g. Fall Lake, which is higher moose density.

Sixth Update as of September 1, 2022:

Outcome #1: Ongoing. No change from previous reporting. We are currently incorporating data on Minnesota moose sightings to further refine mapping of aquatic habitats and determine high-to-low moose locations.
Outcome #2: Complete. No change from previous reporting. Discussions with moose experts is ongoing in order to best determine how to explore the relationship between high and low occurrence and aquatic habitats.

Seventh Update as of March 1, 2023:

Outcome #1: Nearly complete. We are near to producing our first draft of an aquatic habitat map. This will be refined and finalized in the next couple of months.
Outcome #2: Complete. No change from previous reporting. Discussions with moose experts is ongoing in order to best determine how to explore the relationship between high and low occurrence and aquatic habitats.

Final Report as of June 30, 2023 (to be submitted before August 15, 2023):
Completed.

REVISED Final Report as of April 14, 2025:

Activity 1 was completed.

The habitat suitability model for aquatic moose habitat is a tool designed to predict the areas where moose are most likely to be found in aquatic environments (Outcome 1), based on specific environmental variables that influence their behavior, survival, and reproductive success. The model assigns a numerical score (from 0 to 1; see figure below) to different locations based on various environmental factors that influence moose presence, such as water availability, vegetation type, water depth, temperature, and proximity to forested areas (i.e. geospatial data layers). These factors are weighted according to their importance for moose survival and behavior. The model integrates geospatial data to create detailed habitat maps. These maps predict where moose are most likely to be found. These predictions can then be tested with future field observations. Now that the map is developed, it can be tested/validated with empirical field data, such as moose sightings or telemetry tracking, to ensure its accuracy.
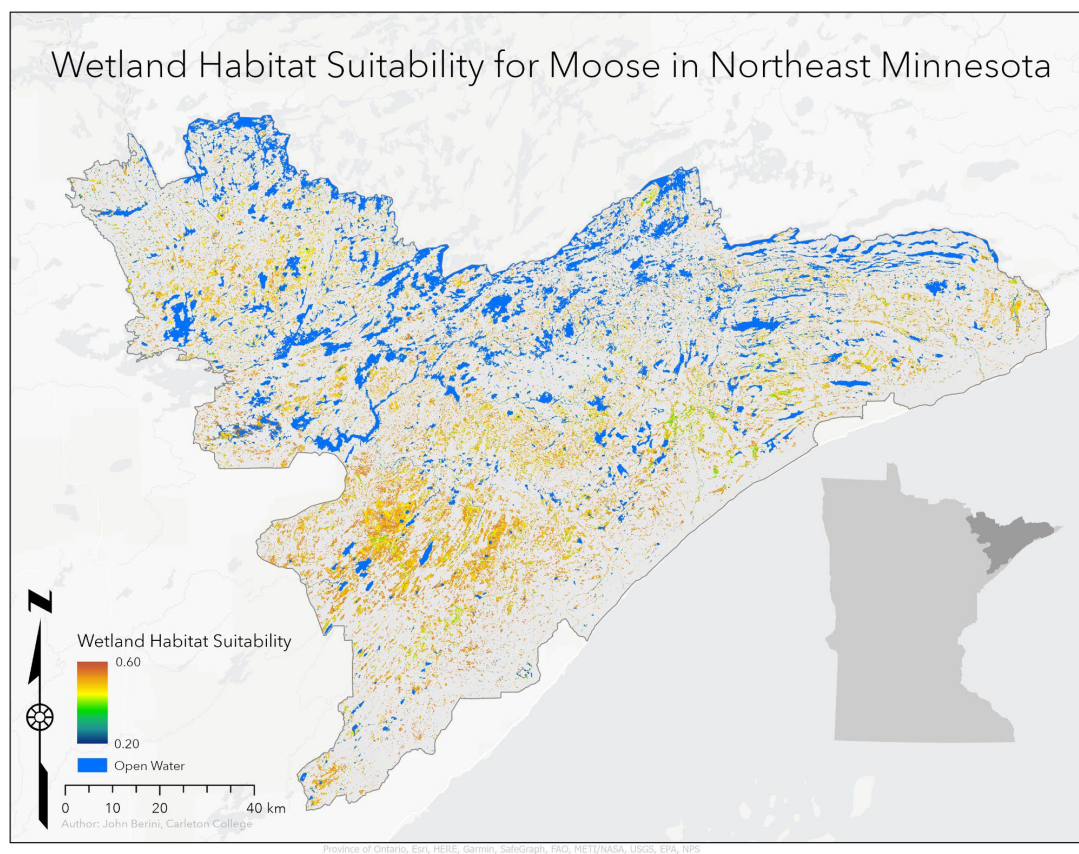
Based on existing literature and conversations with regional biologists, high-to-low moose use across water bodies was identified for the following potential study areas (Outcome 1): 1) 6 lake/pond complexes in the Greater Voyageurs Ecosystem (Saint Louise County), e.g. Ash Lake, Long Lake, Elephant Lake, all of which are low moose density and 2) 6 lakes accessible from the University of Minnesota Hubachek Research Center (Lake County), e.g. Fall Lake, which is in an area with a higher moose density.

Field sampling study design was developed (Outcome 2) but not implemented due to COVID-19 restrictions. In summary, the field sampling would have included measuring moose browsing, water quality indices, fish diversity, and macrophyte coverage along littoral zone transects in each study lake.

The sampling design developed was designed to asses the relationship between moose density (MN DNR moose survey grid; please see below; DelGuidice 2018) and lake survey data (MN DNR Lake Survey

Program). Lake surveys consist of periodic monitoring of fish populations, water chemistry, and fish habitat. Lake survey data is used to track fish population trends. The lake survey database contains information for about 4,000 different waters, including lakes across the aerial moose survey area. Assessing the relationship between moose density and lake survey data was designed and developed to determine the potential for positive feedbacks from moose foraging.

To determine if increased foraging by moose is related to increased turbidity and/or primary production in lakes, we developed methods and a sampling design to measure chemical and biological characteristics in a number of lakes across a moose density gradient. To characterize the water chemistry and trophic state of each lake, the plan was to collect two pelagic, surface measurements of water temperature, conductivity, pH, dissolved oxygen (DO), total algae (chlorophyll a and phycocyanin), and Secchi depth. In addition, the plan was to measure dissolved oxygen and temperature with depth at the deepest part of the lake to determine if each lake is stratified with respect to temperature and if oxygen is present throughout all depths during time of sampling. In addition to these measurements, all variables (with the exception of Secchi depth) were to be collected at each fish sampling site.

The data analyses developed would have compared moose foraging effects on lake variables using multiple linear regression and generalized mixed effect modeling. This field sampling would have allowed us to assess whether aquatic habitat map for moose.   primary productivity and turbidity measurements are related to moose foraging via multiple linear regression and/or mixed effect models.

While we were not able to collect fish due to COVID-19 restrictions, a sampling plan was developed after meeting with regional biologists (Outcome 2). In each focal lake, the plan was to measure fish diversity using three to six fyke nets set perpendicular to shore in one to five m of water. Fish data were to be recorded as catch per unit effort (CPUE) where the unit of effort will be one net night. For each lake, an average of total fish abundance (fish per night) was to be calculated by averaging catches across all fyke nets This would have allowed the assessment of whether fish abundance and fish species diversity measurements (species richness and Shannon's diversity index) are related to moose foraging via linear regression and/or mixed effect models. To further evaluate fish community change across a gradient of moose density, we planned to employ nonmetric multidimensional scaling (NMDS) ordination (McCune and Grace 2002). This method would have allow us to determine if fish communities are different in lakes with different moose densities. During the planned but not realized summer sampling, we planned to visually assess the littoral zone of each lake to estimate proportion dominated by emergent, surface, and submerged aquatic vegetation. We were going to survey using a presence/absence approach to establish the frequency of occurrence for species (Madsen and Bloomfield 1993). Snorkling or a plant rake collection approach was to be used to sample species. This method is useful to establish basic plant coverage and community composition.

After meeting with regional wetland and remote sensing faculty at University of Minnesota, we also develop novel methods to use a combination of acoustic sampling and remote sensing to quantify plant coverage, i.e. biovolume. Percent vegetation biovolume (also known as Percent Volume Inhabited or PVI) represents the percent of the water column occupied by plant matter at specific locations, usually GPS point features. Biovolume is plant canopy height divided by water depth multiplied by 100 averaged over 5-30 pings bound to each GPS location along a traveled path. Biovolume ranges from 0% (bare bottom) to 100% (vegetation growth near to the surface). In addition to being visually intuitive, biovolume is an indicator of surface growth and fish habitat conditions. Where feasible will use current 'fish finder' technology (LowranceTM and Simrad SoundersTM and chartplotters) to collect aquatic data along 1-2m depth contours. Data will then be processed automatically by algorithms (e.g. BioBase EcoSound) to yield aquatic an estimate of aquatic plant coverage.

While the above field sampling was not realized, the design of these methods and approaches is valuable to future natural resource research and environmental monitoring efforts in Minnesota.

Activity 2: Assess moose effects on aquatic habitats, explore potential for positive feedbacks, and develop policy recommendations.
Description: We will use multiple methods to measure how aquatic foraging by moose affects key lake or pond

productivity attributes, plants, and fish diversity. To determine if increased foraging by moose is related to increased turbidity and/or primary production in lakes, we will measure chemical and biological characteristics in a number of lakes across a moose density gradient. The exact number of lakes to be sampled will depend on field conditions. Our hope is to sample at least a dozen lakes (N=12) across a gradient of moose density. This number could subsequently increase depending on access and feasibility. In each focal lake, fish diversity will be measured using three to six fyke nets. During summer sampling, we will visually assess the littoral zone of each lake to estimate proportion dominated by emergent, surface, and submerged aquatic vegetation. Snorkeling or a plant rake collection approach will also be used to sample species.

ACTIVITY 2 ENRTF BUDGET: $134,800

Outcome	Completion Date
1. *Measure moose foraging effects on aquatic habitat primary productivity and turbidity.*	Feb. 1st 2021
2. *Measure fish diversity associated with moose foraging in aquatic habitats*	Feb. 1st 2021
3. *Quantify aquatic plant coverage across a spectrum of high-to-low moose foraging*	June 1st 2021

First Update March 1, 2020

For Activity 2, planning for these outcomes is ongoing. The COVID-19 pandemic, Minnesota's stay-at-home order, and consequent University of Minnesota restrictions on research activities has challenged our progress this spring and will likely affect our field work throughout the summer, but it is uncertain as to how at the time of this reporting.

Second Update September 1, 2020

As before for Activity 2, planning for these outcomes is ongoing. The COVID-19 pandemic, Minnesota's stay-at-home order, and consequent University of Minnesota restrictions on research activities has challenged our progress during the summer as expected. We still may be able to complete this Activity during summer 2021 and possibly still meet the completion dates for most outcomes in this activity.

Third Update March 1, 2021

Ongoing and same as previous reporting.

Fourth Update September 1, 2021

Ongoing and same as previous reporting.

Fifth Update March 1, 2022

Ongoing and same as previous reporting.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Please update Activity 2 and report on any field work that was done in 2021. Your previous updates indicated there was a plan for this. Did these data collection trips occur? Were they successful? If not, please provide an update as to what will occur this summer.

Data collection trips have not occurred in summer 2021. Field sites (identified in Activity 1) were visited in summer 2022 to determine suitability for data collection.

This summer we are also assessing aquatic plant data that is available databases: 1) Minnesota Biological Survey Lakes and Aquatic Plant data. In the course of these surveys, every aquatic and emergent plant species observed in the lake was recorded, as well as a limited number of shoreline species. 2) Lake Water Quality and Assessment Program, which assesses 3100 Lakes in Minnesota and produces individual lake assessments that are updated annually. These databases provide lake water quality and vegetation data that can then be analyzed together with moose density to determine assess the relationship between moose and aquatic habitats.

Sixth Update as of September 1, 2022:
Ongoing Instead of field sampling, which could not be accomplished due to COVID restrictions, we will use data collected by the Minnesota DNR on the Minnesota [Biological Survey Lakes and Aquatic Plant Data](#) and the [Fish-based Index of Biotic Integrity (IBI) Scores.](#) Will use additional data sources depending on their applicability, e.g. [Assessed Waters](#).

Seventh Update as of March 1, 2023:
Ongoing: The data layers previously reported have been incorporated into the aquatic habitats mapping.

Final Report as of June 30, 2023 (to be submitted before August 15, 2023):
Completed.

REVISED Final Report as of April 14, 2025:
Activity 2 was not completed. The reason it was not fully completed was due to COVID-19 constraint on field sampling. Due to these constraints we worked with LCCMR staff to modify our approach to best address the project objectives in the absence of field work. This resulted in a pivot to using pre-existing, landscape-level data and developing an aquatic habitat suitability index model approach and integrated aquatic habitat map.

Activity 3: Create short documentary film on moose and aquatic habitats
Description: We will storyboard, script, and collect footage for a short documentary film highlighting the importance of aquatic habitats to moose and illustrating the ways in which aquatic foraging by moose in turn affects small lakes and ponds.

Activity 3 BUDGET: $14,000

Outcome	Completion Date
1. Storyboard and script documentary film	May 1st 2020
2. Collect footage	June 1st 2021
3. Complete preliminary film editing	June 1st 2021

First Update March 1, 2020

Outcome #1: This outcome is ongoing. The PI has met with a professional photographer/videographer that specializes in wildlife. Storyboarding specific shots to aim to capture in the field is nearly complete, but we have realized that it is likely subject to ongoing revision depending on what is recorded; the same applies to the accompanying script. The PI, at no cost to the project, worked with a professional graphic artist to develop a logo for this project, pictured below.

Outcomes #2 & #3: At this time, it is unknown the extent to which the COVID-19 pandemic, Minnesota's stay-at-home order, and consequent University of Minnesota restrictions on research and travel will impact these outcomes.

Second Update September 1, 2020
Outcome #1: This outcome is ongoing. We have established a collaboration with [Benjamin Olson](#), a professional, Minnesota based photographer to help generate content, both photo and video, for Activity #3. Storyboarding specific shots to aim to capture in the field is nearly complete, but we have realized that it is likely subject to ongoing revision depending on what is recorded; the same applies to the accompanying script.
Outcomes #2 & #3: This outcome has begun and is ongoing. Some footage from the Greater Voyageurs Ecosystem has been recorded.

Third Update March 1, 2021

Outcome #1: Ongoing and same as previous reporting.

Outcomes #2 & #3: Ongoing and same as previous reporting.

Fourth Update September 1, 2021

Ongoing and same as previous reporting.

Fifth Update March 1, 2022

Ongoing and same as previous reporting.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Please update Activity 3—do you have a plan in place if you cannot capture enough moose footage? What is it? How do you intend to obtain more footage? One of the goals of this project is producing educational materials. Have these materials been produced? Is there a plan to produce them over the next year? If so, what is it?

Yes, if we are unable to capture enough moose footage my plan is to 1) use animation to tell the story of moose and aquatic habitats and 2) expand the area from which we try to obtain footage, trying to target areas that are high moose density. No educational materials have been produced yet. I have already explored the possibility of working with graphic specialists to produce a short animated film. This work could begin this fall and would meet the goal of highlighting the importance of aquatic habitats to moose and illustrating the ways in which aquatic foraging by moose in turn affects small lakes and ponds. I would still like to pursue filming moose as well.

Sixth Update as of September 1, 2022:
Ongoing. Efforts to record enough moose footage are ongoing. Discussions have begun with an animation specialist to complete the activity even if new moose footage from the wild is not available.

Seventh Update as of March 1, 2023:
Ongoing. Currently we are working with Science Animated (www.sciani.com) to complete this activity. I doubt this activity will be complete by the end of the project, but should be complete to meet the final reporting deadline.

Final Report as of June 30, 2023 (to be submitted before August 15, 2023):
This activity was not completed as originally designed due to 1) University of Minnesota limitations placed on fieldwork due to the COVID pandemic and 2) the stochastic nature of filming wildlife.

REVISED Final Report as of April 14, 2025:
Activity 3 was only partially completed due to 1) University of Minnesota limitations placed on fieldwork due to the COVID pandemic and 2) the stochastic nature of filming wildlife.

Outcome 1 was completed: A storyboard and script documentary film draft was completed, along with a documentary project logo (see attachment "Storyboard: Short Documentary Film on Moose and Aquatic Habitats"). It was expected that we would revise this draft depending on footage collected.

Outcomes 2 and 3 were not completed.

IV.   DISSEMINATION:

Description: Project results will be disseminated through professional presentations (The Wildlife Society annual meetings, Minnesota chapter), peer-reviewed publications, and a mini-documentary.

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

First Update March 1, 2020
Since this is the first reporting period, there are no dissemination outcomes to share at this time. Professional presentations, peer-reviewed publications, and the mini-documentary have not been completed.

Second Update September 1, 2020
There are no dissemination outcomes to share at this time. Professional presentations, peer-reviewed publications, and the mini-documentary have not been completed.

Third Update March 1, 2021
There are no dissemination outcomes to share at this time. Professional presentations, peer-reviewed publications, and the mini-documentary have not been completed.

Fourth Update September 1, 2021
There are no dissemination outcomes to share at this time. Professional presentations, peer-reviewed publications, and the mini-documentary have not been completed.

Fifth Update March 1, 2022
There are no dissemination outcomes to share at this time. Professional presentations, peer-reviewed publications, and the mini-documentary have not been completed.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Sixth Update as of September 1, 2022:
Ongoing. Since the last update, preparation of one professional PowerPoint presentation has been completed.

Seventh Update as of March 1, 2023:
Ongoing. Since the last update, two guest lectures and have been given to undergraduates at the University of Minnesota. This project will be disseminated at the 55th North American Moose Conference and Workshop in Grand Portage, MN, May 22-26.

Final Report as of June 30, 2023 (to be submitted before August 15, 2023):
Exhibit & Interpretation' meeting at the Minnesota Zoo to share results with the top moose experts in the state. We presented project information to the National Park Service, Voyageurs Conservancy, and attendees of the Minnesota chapter of The Wildlife Society meetings. Visual content for educational outreach and wildlife management has been created, for example a project logo and habitat map. These are broader impact and research tools, respectively. This project also resulted in two peer-reviewed, open-access scientific publications.

5/14/25 LCCMR Staff note: some of the meetings and outreach efforts mentioned above may have occurred before the July 1, 2019 start of this award. ENRTF funds were not used for work or efforts prior to July 1, 2019.

REVISED Final Report as of April 14, 2025:
Project results have been shared with natural resource professionals via slide presentations. We attended a two- day 'Moose Exhibit & Interpretation' meeting at the Minnesota Zoo to share results with the moose experts to support efforts to update the zoo's moose exhibit.

We presented information on moose aquatic ecology to the National Park Service, Voyageurs Conservancy, and attendees of the Minnesota chapter of The Wildlife Society meetings. This presentation content is available upon request for educational outreach and is held by the PI at the University of Minnesota. The slide presentations help achieve broader impact goals of this project.

This project also helped to indirectly support and inspire two peer-reviewed, open-access scientific publications. While these publications did not incorporate new data collected as part of this project the work to complete these publications did directly benefit and was supported by efforts of this project; the intellectual work of this project helped in the formation and articulation of these manuscripts. In other words, these papers began before this project and formed some of the basis for developing this project.

Professional presentations:
1. May 10th, 2018 - Voyageurs National Park Association (note a presentation about moose in the attached flyer), St. Paul, MN
2. February 19th, 2019 Annual Minnesota meeting of The Wildlife Society, Willmar, MN
3. August 20th and 21st 2019 - Minnesota Zoo, Apple Valley, MN. Please see notes from Zoo meeting detailed key research findings shared and disseminated by the group.

5/14/25 LCCMR Staff note: ENRTF funds were not used for the presentations in 1 & 2 above, which occurred before the July 1, 2019 start of this award.

Peer-review publications that helped disseminate information about the importance of aquatic habitats to moose:
1. Tischler, K.B., Severud, W.J., Peterson, R.O. and Bump, J.K., 2019. Aquatic macrophytes are seasonally important dietary resources for moose. *Diversity*, *11*(11), p.209.

2. Bump, J.K., 2018. Fertilizing riparian forests: nutrient repletion across ecotones with trophic rewilding. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1761), p.20170439.

5/14/25 LCCMR Staff note: ENRTF funds were not used for the publications in 1 &2 above, which were published before the July 1, 2019 start of this award.

V. ADDITIONAL BUDGET INFORMATION:
A. Personnel and Capital Expenditures

Explanation of Capital Expenditures Greater Than $5,000: The YSI sonde sensor package ($ 17,700) is a key piece of equipment to measure lake primary productivity, turbidity, conductivity, temperature, dissolved oxygen, and total algae in aquatic habitats. For this project, it is essentially a mobile lab to assess important parameters in the aquatic habitats available to moose. This equipment will continue to be used in this capacity through its useful life after the project's completion.

Explanation of Use of Classified Staff:

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

Enter Total Estimated Personnel Hours for entire duration of project: 5,200	Divide total personnel hours by 2,080 hours in 1 yr = Total FTE 2.5

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

N/A   N/A

VI. PROJECT PARTNERS:

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

Name	Title	Affiliation	Role
TBD	Masters Student	University of Minnesota	Research Assistant
TBD	Co-project manager	University of Minnesota	Co-leader; fish specialist
Joseph K. Bump	Project leader	University of Minnesota	Project PI

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

Name	Title	Affiliation	Role
Steve Windels	Research Biologist	National Park Service	Advise field sampling

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:
This project will provide foundational data and information for aquatic habitat monitoring for moose.

VIII. REPORTING REQUIREMENTS:

- Project status update reports will be submitted March 1 and September 1 each year of the project.
- A final report and associated products will be submitted between June 30 and August 15, 2023

IX.   SEE ADDITIONAL WORK PLAN COMPONENTS:

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

Environment and Natural Resources Trust Fund <u>Final Report</u>
Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 03L

Project Title: Mapping Aquatic Habitats for Moose
Project Manager: Joseph K. Bump
Organization: University of Minnesota Project Budget: $199,000
Project Length and Completion Date: 4 years, June 30, 2023
Today's Date: April 14, 2025

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits): *subtotal = $164,900*
Masters student, field work, analysis and modeling, paper publishing, and co-lead public outreach: (56% salary, 44% benefits) 50% FTE for 3 years.
Co-project management, co-analysis, paper publishing, and co-lead public outreach and communication: (82.3% salary, 17.6% benefits) 50 % FTE for 2 years.
Undergraduate Wildlife Field Assistant to assist with field work and data entry: (100% salary) 30 % FTE for 2 years.
Subtotal Personnel
Professional/Technical/Service Contracts
Equipment/Tools/Supplies
Fyke nets (6 at $500 each = $3,000) to sample fish communities;
Capital Expenditures Over $5,000
YSI sonde sensor package to measure lake primary productivIty, turbidity, conductivty, temperature, dissolved
Travel expenses in Minnesota
Mileage, lodging, for in-state travel by all project personnel to and from field sites for two seasons (multiple trips), data sharing partner offices (MN DNR, federal agencies, tribal wildlife agencies) and outreach presentation sites. All trave willl adhere to the commissioner's plan. (1) Vehicle Rental = $ 3,336 (2) Vehicle mileage = $2,580 (3) Room rentals = $ 4,084
Other
Publishing page costs for 2-3 peer-reviewed papers
COLUMN TOTAL
OTHER FUNDS CONTRIBUTED TO THE PROJECT
Non-State: N/A
State: N/A
In kind:$88,560 Forgone organized research indirect costs associated with this project (54% MTDC). $5,000 from Gullion Chair and UMN research start-up funds to Project Lead JK Bump will be used for travel to present results at regional, national (e.g. The Wildlfie Society) or international professional conferences (e.g. Conservation Biology). $20,000 from UMN research start-up funds to Project Lead JK Bump will be used for summer salary to deliver 3 weeks of summer salary for the project (75% salary, 25% benefits) 6% FTE for 2 years. $5,000 + $20,000 = $25,000
PAST AND CURRENT ENRTF APPROPRIATIONS
Current appropriation: N/A
Past appropriations: N/A