Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

Date of Report: 15 January 2014

Date of Next Status Update Report: 1 May 2015

Date of Work Plan Approval:

Project Completion Date: 31 June 2017

Does this submission include an amendment request? No

PROJECT TITLE: Impacts of forest quality on declining Minnesota moose.

Project Manager: James D Forester

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Location: St. Louis, Lake, and Cook Counties (see Figure 1).

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$300,000**
	Amount Spent:	**$0**
	Balance:	**$300,000**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 05l

Appropriation Language:
$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota in cooperation with the Department of Natural Resources to link regional patterns of moose abundance through time to the distribution of food and cover and determine if this distribution affects the diet and survival of individual moose. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Impacts of forest quality on declining Minnesota moose.

II. PROJECT STATEMENT:

The Minnesota moose population is declining dramatically and has become a growing concern for conservation. In addition to being an iconic species of northern Minnesota, moose are keystone herbivores that are an important component of Minnesota's forested ecosystems. The specific mechanism causing their rapid decline has not been fully uncovered because many factors affect how well moose survive and reproduce. Ultimately, the most important tool available to natural resource managers is their ability to manipulate the spatial distribution and diversity of high-quality habitats (Figure 2). Management decisions will clearly benefit from scientific guidance to ensure manipulations have maximum impact on stabilizing the moose population in Minnesota.

The Minnesota Department of Natural Resources (MNDNR), the Grand Portage Band of Lake Superior Chippewa (GPBLSC), and the University of Minnesota began a moose tracking effort in 2013 to determine cause-specific mortality within the moose population (128 GPS collars were deployed). In addition, Dr. Ron Moen (NRRI) is working on a moose habitat restoration project in which he is assessing how food availability, quality, and consumption by moose changes in forests with different disturbance histories. We propose to build upon both of these LCCMR-funded research projects to explore how the landscape context in which individual animals live can directly affect the animals' diet and their subsequent body condition and mortality risk. Understanding how forest age, structure, and composition can affect the distribution of food and cover (and thus impact the movement patterns of moose) is critical to inform broad-scale management efforts that are aimed to improve the forest landscape for moose and thus stabilize the population.

Our *broad aim* is to link the behavior, diet, and survival of moose to the spatial distribution of food and cover. Our team will build upon existing moose research in the state to address two primary *research goals*:

1) *Regional Scale*: Link regional patterns of moose abundance through time to the geographic distribution and relative forage quality of different land-cover types and forest stand ages.

2) *Local Scale*: Determine if the distribution of resources affects the diet of individual moose and whether dietary differences among animals are associated with variation in body condition or mortality risk.

This will be the first study to link the movement behavior and landscape context of individual moose (e.g., the distribution of food and cover within an animal's home range) to the animals' diet, body condition, and mortality risk. It will allow us to place the moose movement, mortality, and forage quality data already being generated by LCCMR funding into a detailed ecological and behavioral framework that will provide critical and timely insight into the causes of the moose population decline.

III. PROJECT STATUS UPDATES:

Project Status as of 1 May 2015:

Project Status as of 1 May 2016:

Project Status as of 31 June 2017:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Linking moose abundance to broad-scale distributions of food and cover that change across space and through time.

Description: We hypothesize that broad-scale changes in the arrangement (rather than simply the abundance) of important cover types (e.g., young and mature forest, wetlands) measured at the level of four townships or larger will be linked to changes in moose abundance. Areas dominated by one cover type (e.g., young forest) will be avoided in preference for areas that contain a mixture of cover types that provide reduced distances between thermal cover and high quality forage. We will use a combination of USFS Forest Inventory and Analysis (FIA) data and satellite data (both collected repeatedly over the last 13 years) in conjunction with data from the MNDNR moose survey to examine how the moose population has responded to changes in distributions of resources across its Minnesota range.

Our broad-scale analysis will use data from the 2012 FIA database in addition to time series of classified satellite images. The FIA data will be analyzed using geographic information system (GIS) techniques to examine differences in the amount and types of habitat available to the moose population in different survey zones. We will also create a new satellite classification for portions of the moose range in NE Minnesota. This classification (based on historic and current satellite images) will be specifically developed to focus on moose habitat and will subsequently be analyzed using Fragstats and texture statistics to describe how the amount and distribution of different land cover types change across space and through time. The results of these two analyses will then be compared with the relative abundance of moose on plots with differing habitat characteristics.

To understand the process that may lead to moose selecting one landscape over the other, we need to understand how forage availability changes across space. We will characterize the forest communities in 61 sites (Figure 1) that represent a range of cover types and known disturbance histories. Our sampling methodology is adapted from previous studies in Superior and Chippewa National Forests and will help us predict how forage resources change in response to land-surface attributes (e.g., soil type, aspect, land cover). These data will allow us to determine whether coarse distributions of food and cover are correlated to local estimates of moose abundance.

Finally, to quantify how the moose population is responding to changes in the landscape, we need to describe how the spatial distribution of the animals has changed through time. The existing population estimation model was designed to provide a region-wide population estimate. We will collaborate with the MNDNR researchers to refine the model so that it will allow for finer-grained analysis. This approach will allow us to make relative estimates of local abundance over the last 8 years. Using these results we will determine if there is spatial variation in local moose population trends and whether this variation is linked to changes in landscape characteristics.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 127,878
Amount Spent: $ 0
Balance: $127,878

Activity Completion Date: *September 2016*

Outcome	Completion Date	Budget
1. Analyze data from 1,258 FIA plots and the moose survey data to determine how broad-scale patterns of landscape change are linked to moose population dynamics.	December 2014	$ 8,570
2. Produce a new classification of satellite data for NE MN to show how the distribution of high-quality moose habitat has changed in recent years.	September 2015	$ 36,848
3. Identify how the species composition of moose forage changes among land-cover types and in response to stand age.	December 2015	$ 69,448
4. Publish a spatially-explicit analysis of how moose population density changes in response to availability and arrangement of forage in the landscape.	September 2016	$ 13,012

Activity Status as of 31 January 2015:

Activity Status as of 1 May 2015:

Activity Status as of 31 January 2016:

Activity Status as of 1 May 2016:

Activity Status as of 31 January 2017:

Final Report Summary:

ACTIVITY 2: Linking the distribution and quality of food and cover to moose diet, body condition and mortality risk.
Description: We will use stable isotope analysis to determine how the distribution of food and cover affects diet and whether individual movement behavior allows some individuals to have higher quality diets in landscapes with lower quality habitat. We hypothesize that diets of individual animals will reflect the forage available to them within their home range area and that animals that live in areas with lower quality forage or larger distances between food and cover will have lower body condition and be more susceptible to mortality. By analyzing the carbon and nitrogen isotopic ratios of moose body tissues collected at capture and after death, we can assess individual moose diet and habitat use on timescales from several weeks to several years. We will combine these data with GPS locations of the same animals to test if the moose are eating what is available to them. This will allow us to determine the degree to which landscape context (e.g., the abundance, spatial distribution, and biochemical signature of land-cover types within an animal's home range) is driving the movement pattern and diet of the animal. We will then determine if dietary differences among individuals can explain variation in mid-winter body condition or mortality risk. These results will provide suggestions on how to change forest management to benefit moose.

During Years 1 and 2, we plan four field sessions of unequal duration each utilizing two field teams: (1) in an early spring session we will sample leaves and wood of common forage in one replicate plot of each land-cover type; (2) in a late spring session, we will revisit the same sites to describe early phenological changes in vegetation quality and isotopic composition; (3) in a longer summer session, we will focus on the entire range and sample leaves, wood, and fruiting bodies in three replicates of each land-cover type; (4) a winter session will focus on woody forage in one replicate of each treatment. As field conditions allow, the winter plots will be the same as those sampled in spring, ensuring seasonal sampling of the same plots over two years, and in each of these plots we will mark specific plants for replicate sampling. This sampling scheme will control for seasonal and inter-annual variation in forage composition over the course of the project. In Years 2 and 3 we will use the movement data collected from the GPS collars to ensure that we sample plants within known home ranges; this may require establishing some new plots. During winter sampling in Years 2 and 3, we will backtrack moose paths known from collar data to sample consumed vegetation and collect snow urine. Given the number of plots and samples planned, flexibility in sampling during Years 2 and 3 is possible and will allow us to concentrate on known home ranges without sacrificing the comprehensiveness of sampling. Year 3 will also include revisits of a subset of sites and marked plants (this year will also include substantial ground truthing efforts for the satellite classifications).

The stable isotopic composition of vegetation sampled in the field will be related to that of moose tissues we collected at capture. To develop robust estimates of diet, we need to analyze a large number (7368) of individual plant and animal tissue samples. For the moose, we will primarily focus on hair and hoof keratin, although we will opportunistically sample feces, bone, and tooth enamel from dead animals. By sampling moose tissues with different elemental turnover times that integrate diet over different intervals and for which isotope

enrichments relative to diet are known, we can assess individual moose diet and habitat use on timescales from days to months to years.

We will use statistical models to describe the survival for adult moose as a function of animal characteristics (e.g., age, sex, behavioral phenotype, short- and long-term diet based on stable isotope analysis, etc.) and landscape covariates (e.g., road density, land cover proportions, land cover patch metrics, etc.) calculated within each animal's home range. We will then use these results to develop spatially explicit risk maps that we can compare to the local moose population trajectories developed in Activity 1. Combining these two sources of data will help us understand if the distribution of food and cover are mechanistically linked to the population dynamics of moose in Northern Minnesota. The results from this analysis will allow us to make specific management recommendations related to the distribution and abundance of different land-cover types that will increase the probability of stabilizing the moose population.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 172,122
Amount Spent: $ 0
Balance: $172,122

Activity Completion Date: *June 2017*

Outcome	Completion Date	Budget
1. Assess the nutrient quality and stable isotopic concentration of forage available in each collared animal's home range.	November 2015	$118,413
2. Develop a time series of diet over the previous year for each collared moose (n=129) using stable isotopic analysis of hair collected at capture and after death.	December 2015	$15,736
3. Assess whether forage availability or diet affect the rates of survival.	December 2016	$33,172
4. Provide specific forest management recommendations to experimentally improve the landscape for moose in the areas of their range where the animals are most vulnerable.	June 2017	$4,801

Activity Status as of 31 January 2015:

Activity Status as of 1 May 2015:

Activity Status as of 31 January 2016:

Activity Status as of 1 May 2016:

Activity Status as of 31 January 2017:

Final Report Summary:

V. DISSEMINATION:

Description: A fact sheet that summarizes our findings will be distributed to LCCMR members and land managers at the state and federal level; this will also be made available on the UMN Department of Fisheries, Wildlife, and Conservation Biology website. In addition, several manuscripts will be written and submitted for publication in peer-reviewed journals. Results will be presented at state and national wildlife and ecology conferences (e.g., the annual Minnesota Moose Meeting, The Wildlife Society [both state and national conferences], the Ecological Society of America, and the International Association of Landscape Ecology). All publications resulting from this project will be made available through the FWCB website or Open Access journal websites.

We also expect that there will be a large amount of informal dissemination because we will be working closely with researchers and managers from the Department of Natural Resources, The Nature Conservancy, the Grand Portage Band of the Lake Superior Chippewa, the National Park Service, and the US Forest Service. These researchers will take the results of our study into consideration as they make management decisions and will work with us to ensure that our data products and research papers reach a broad audience within their agencies.

Finally, we will continue to pursue public outreach through the Bell Museum of Natural History at UM, which brings University research to the public onsite within the BMNH and offsite through community venues, traveling exhibits, and film productions. We will continue to collaborate with them to develop a unique learning environment that integrates interactive media that presents our on-going research with the existing detail-rich and aesthetically compelling traditional diorama in the BMNH. The decline of moose in Minnesota is of significant public interest, and we expect the presentation of this research to improve public understanding of both the scientific process and the state of this iconic species.

Status as of 31 January 2015:

Status as of 1 May 2015:

Status as of 31 January 2016:

Status as of 1 May 2016:

Status as of 31 January 2017:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$ 150,969	1 project manager at 8%FTE for 3y; 1 field manager at 38% FTE for 3y; 1 lab manager at 4% FTE for 3 y;1 lab technician at 8% FTE for 3 y; 1 research associate at 6% FTE for 1 y; 2 undergraduate research assistants at 19%FTE for 3y; 1 PhD student at 14% FTE for 3y.
Professional/Technical/Service Contracts:	$ 83,944	1 contract for laboratory analysis of plant and tissue samples; 2 contracts for satellite imagery analysis.
Equipment/Tools/Supplies:	$ 9,980	Lab supplies for stable isotope analysis; field equipment (tapes, sample bags, etc)
Capital Expenditures over $5,000:	$ 5,845	High precision GPS for relocating sites and individual plants for resampling.
Fee Title Acquisition:	$ 0	
Easement Acquisition:	$ 0	
Easement – Long-term Monitoring, Management, and Enforcement	$ 0	
Professional Services for Fee Title and Easement Acquisition:	$ 0	

Printing:	$ 0	
Travel Expenses in MN:	$ 49,262	Travel to study area by staff and technicians (1 fleet truck for 4mo/y over 3y); lodging and meals for 2-6 crew members for 4mo/y over 3y.
Other:	$	
TOTAL ENRTF BUDGET:	**$ 300,000**	

Explanation of Use of Classified Staff:

Explanation of Capital Expenditures Greater Than $5,000: One Trimble GeoExplorerXT will be purchased for high-resolution field sampling and ground-truthing of satellite classifications. The instrument will continue to be used for similar projects and purposes by the Forester Lab at UMN for the life of the instrument. If the instrument is sold prior to its useful life, proceeds from the sale will be paid back to the Environment and Natural Resources Trust Fund.

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 2.98 FTEs

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0.5 FTEs

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
	$ 0	$ 0	
State			
Purchase and maintenance of 15 moose GPS collars (Forester startup)	$89,463	$ 50,000	Data from these collars will provide the critical data for this project. We will be able to link where animals spend their time to what they are eating and subsequently their body condition.
Graduate Lab Manager (Fox Stable Isotope Lab, 1mo summer salary + 23.1% health and FICA)	$2,400	$ 0	This lab manager will help with the analysis of our samples
Computer equipment dedicated to data analysis and simulation for this project (Forester startup)	$5,558	$ 5,558	These computers will provide the computational power to fit the statistical models we will develop in this project.
Foregone ICR funding (52% MTDC, excluding graduate fringe)	$153,770	$ 0	
In-kind Services During Project Period: Salaries for Forester (1% match), D'Amato (1% match)	$6,550	$ 0	The PIs will be spending substantial time organizing the crews, analyzing data and writing up manuscripts and reports.
TOTAL OTHER FUNDS:	**$ 257,741**	**$ 50,000**	

VII. PROJECT STRATEGY:

A. Project Partners:

The research team will be led by scientists at the University of Minnesota Departments of Fisheries, Wildlife and Conservation Biology (Dr. James Forester), Earth Sciences (Dr. David Fox), and Forest Resources (Dr. Anthony D'Amato).

Partners include the UMN (Dr. Alan Ek), MNDNR (Dr. Michelle Carstensen, Dr. Glenn DelGiudice), TNC (Mark White), and the Grand Portage Band of Lake Superior Chippewa (Dr. Seth Moore).

B. Project Impact and Long-term Strategy:

Opportunities to gain insight into the spatial structure of population demographic rates are rare. The proposed work builds on moose research by the MNDNR to examine how this species (of local economic and cultural importance) is responding to changing landscapes. This study will directly address questions of management concern and will also advance managers' understanding of (1) how animals behaviorally mitigate environmental stress; (2) how behavior and landscape context affect diet, survival, and fecundity; and (3) how broad-scale landscape structure can affect the space use and demographic rates of the moose population. Our ongoing collaborations with state, tribal, and federal agencies will ensure that the research results are broadly disseminated. Likewise, our interaction with the Bell Museum will expose the public to our ongoing efforts to manage and conserve moose in Minnesota.

C. Spending History:

Funding Source	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13	M.L. 2013 or FY14
Forester startup funds			52,500	3,058	

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S):

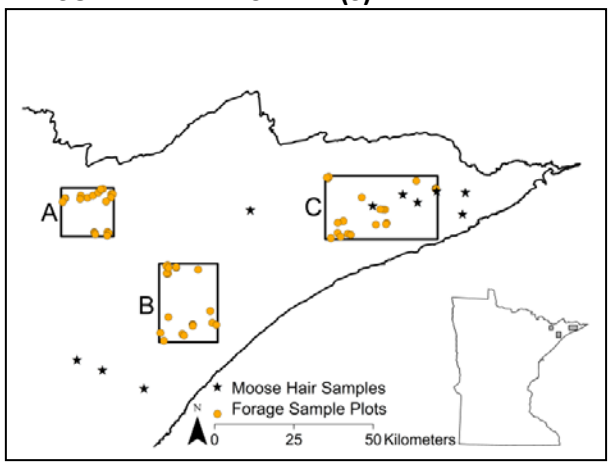

Figure 1. Proposed study area. Boxes indicate stratified sampling regions where preliminary plant samples were collected in June, 2012. Stars indicate locations of preliminary moose hair samples, yellow dots are plant sampling plots.

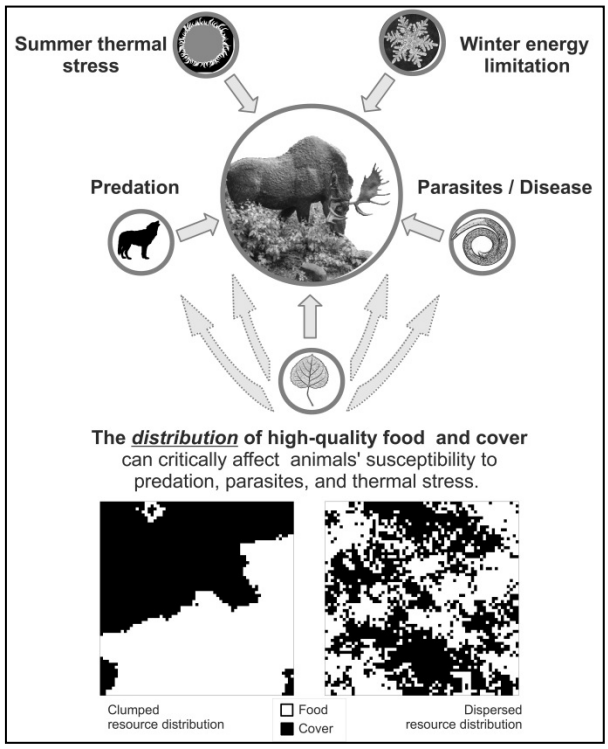

Figure 2: The amount and arrangement of important habitat may affect moose survival.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM:
See attached Research Addendum

XII. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than 1 May 2015, 1 May 2016, and 31 June 2017. A final report and associated products will be submitted between June 30 and August 15, 2017.

Environment and Natural Resources Trust Fund
M.L. 2014 Project Budget

Project Title: Impacts of forest quality on declining Minnesota moose.
Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 05l
Project Manager: James Forester
Organization: University of Minnesota
M.L. 2014 ENRTF Appropriation: $ 300,000
Project Length and Completion Date: 3 years, 31 June 2017
Date of Report: 2014-01-15

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Linking moose abundance to broad-scale distributions of food and cover that change across space and through time.***			***Linking the distribution and quality of food and cover to moose diet, body condition and mortality risk.***				
Personnel (Wages and Benefits)	$76,314	$0	$76,314	$74,656	$0	$74,656	$150,969	$150,969
Field manager - $38,055 (73% salary, 27% benefits); 38% FTE for two years; will lead vegetation sampling effort.								
Faculty (Forester) - $28,808 (84% salary, 16% benefits); 8% FTE for three years; will manage project, and lead analysis of moose movement data.								
Faculty (Fox) - $15,664 (84% salary, 16% benefits); 4% FTE for three years; will supervise the stable isotope analyses								
Lab technician - $13,076 (73% salary, 27% benefits); 8% FTE for three years; will maintain stable isotope lab equipment and assist with analyses.								
Research Associate (David Wilson) - $3,769 (73% salary, 27% benefits); 6% FTE for one year; will take lead on collecting and analyzing the FIA data for the moose range.								
Undergraduate research assistants - $28,745 (100% salary); 2 x 19% FTE over 3 yr; will aid graduate student, field manager, and lab technician with data collection and entry.								
PhD student (John Berini) $22,852 (81% salary, 19% benefits); 14% FTE over three years; will collect plants for stable isotope analysis within animal home ranges, will collect moose browse, hair, and fecal pellets during winter, and will take lead on the analysis of moose isotope concentrations.								
Professional/Technical/Service Contracts								
Isotope analysis (University of Minnesota Stable Isotope Lab) - $58,944; 7368 samples of moose and plant tissue at $8/sample	$0	$0	$0	$58,944	$0	$58,944	$58,944	$58,944
GIS and Statistical Consultants (Peter Wolter, Mark White, TBD) - $26,333; classify historic and current satellite imagery and conduct spatially explicit statistical analyses.	$25,000	$0	$25,000	$0	$0	$0	$25,000	$25,000
Equipment/Tools/Supplies								
Lab supplies (reagents, weigh tins, gas canisters, and other consumable supplies used for stable isotope analysis) - $9,000	$0	$0	$0	$9,000	$0	$9,000	$9,000	$9,000
field equipment (measuring tapes, compasses, flagging tape, sample bags, stakes, etc) - $1,200	$600	$0	$600	$380	$0	$380	$980	$980
Capital Expenditures Over $5,000								
Map-grade GPS unit for precise location of field samples and accurate ground truthing of satellite imagery $5,845				$5,845	$0	$5,845	$5,845	$5,845
Travel expenses in Minnesota								
Travel to study area by project management staff and technicians 4 months/yr for 3 years (1 fleet truck @$779/month, $0.37/mi, 10000 miles/ yr) - $17,040	$8,520	$0	$8,520	$8,520	$0	$8,520	$17,040	$17,040
Room and board for field crew (3 yr of summer and winter field sessions, 4 months/yr, 2-6 crew members at a time, lodging @ $1,500/mo, meals @ $1,185/mo) - $32,222	$16,111	$0	$16,111	$16,111	$0	$16,111	$32,222	$32,222
COLUMN TOTAL	**$126,545**	**$0**	**$126,545**	**$173,456**	**$0**	**$173,456**	**$300,000**	**$300,000**